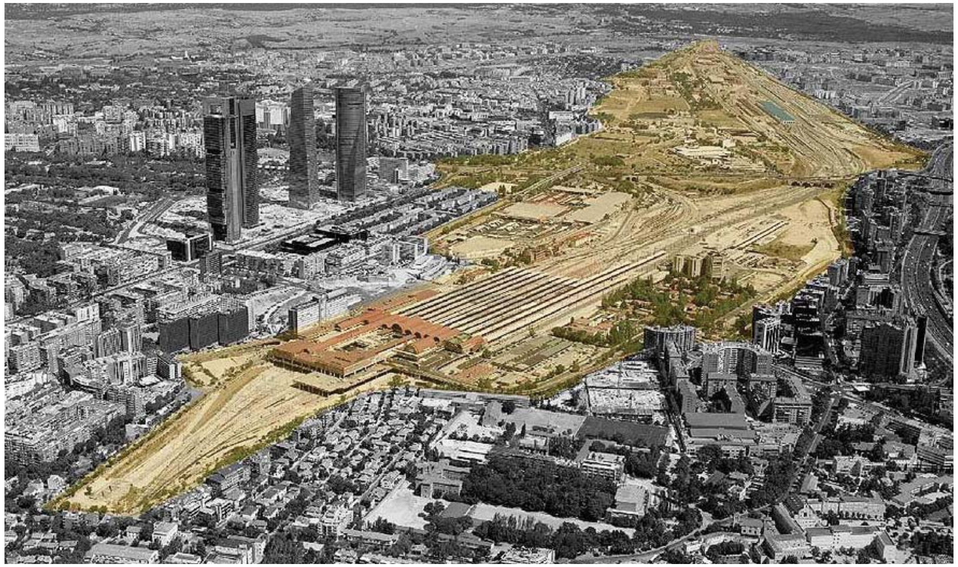
CONSTRUCTION PROJECT

# Chamartín Railways Underground

## Madrid, Spain.



| CLIENT | MADRID CASTELLANA NORTE |
|---|---|
| DATE | 2014 - 2015 |
| LOCATION | Madrid, Spain |
| FIELD OF ACTION | Construction Project |

In 2008 the project "Prolongation of Paseo de la Castellana to the north in Madrid", known as Chamartín Plan, which involved a total investment of 4.200 billion euros in the execution of public infrastructure, was presented.

Within this great performance, where different perspectives and disciplines interact, one of the important areas to analyze is the structural one which consists basically in the covering structure of the tracks. This is because of the constructive implications and affections to the different urban services and traffics and because of its cost.

After the new activation of the Plan in 2014, INES has performed structural and geotechnical consulting and design work throughout 2014 and 2015.

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The final areas to be covered correspond to the edges defined in the General Railway System. The lower plane, approximate at 723 elevation, will remain as railway area and the upper level, urban level, will be located at 733 elevation.

During the preliminary stages, different studies were developed, traffic, geotechnical, affection to existing services, etc.. The optimal solution for covering the existing and future tracks was analyzed from the point of view of the different existing conditions and variables and developed to a level where, on the one hand, it was possible to analyze its feasibility, and suitability for all agents involved and, on the other hand, it could be valued economically. In addition, the various construction aspects that interfere with the railway station operation were raised and analyzed, pointing out which of them have been taken into account and valued economically and which are not. All of the solutions proposed respect the configuration of the current and planned railway tracks lay out, and both horizontal and vertical clearances.

Therefore, during this preliminary stage, various alternatives were studied in which the structural aspects, construction of facilities, railway conditions, etc., were deeply analyzed and agreed with the different administrations involved.

To achieve these goals, the different tasks of the work performed are presented below:

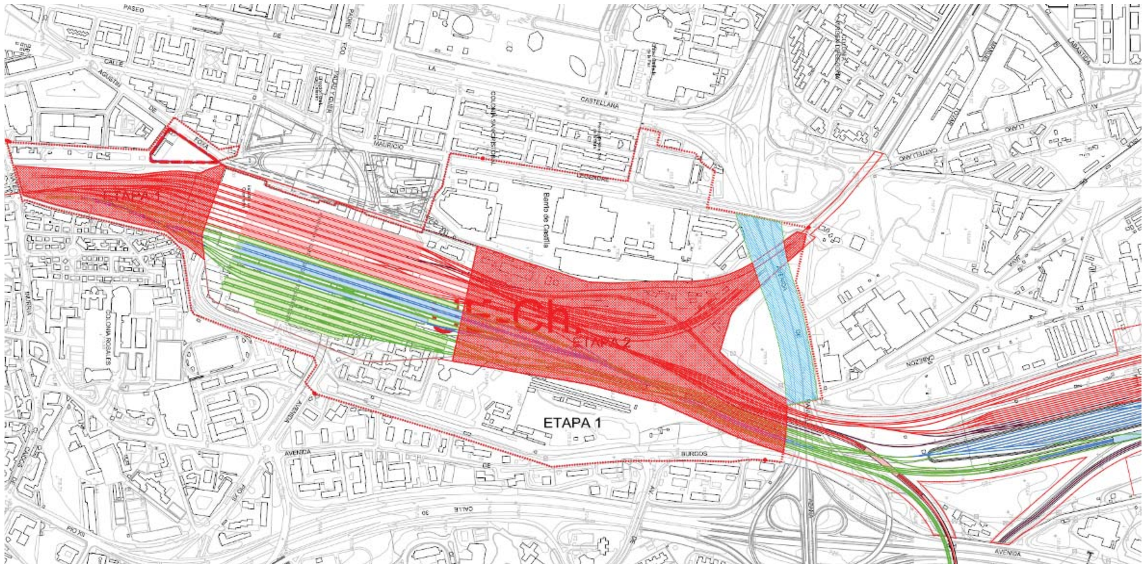
1. Study of the existing information

2. Analysis of the existing constrains for the track covering: architectural, urban, railway, geotechnical, constructive process, structural, etc.

3. Study of alternatives. Pre design and planning of a construction system.

4. Development of the final solution: Geotechnical, structural analysis and cost estimation.

To carry out this work, INES team has been in permanent contact with the other actors of the Plan, to the extent that much of the determining factors and constrains analyzed are based on studies conducted by them.

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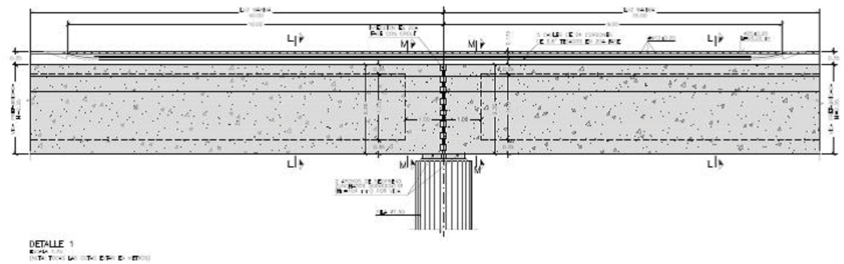
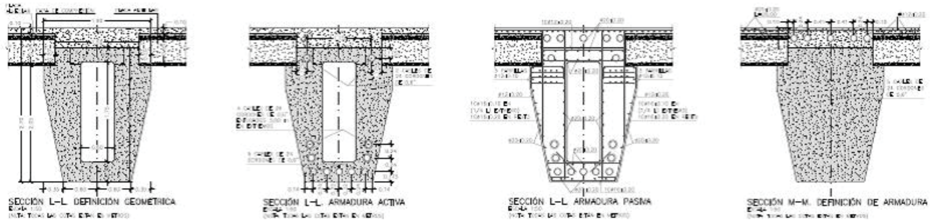
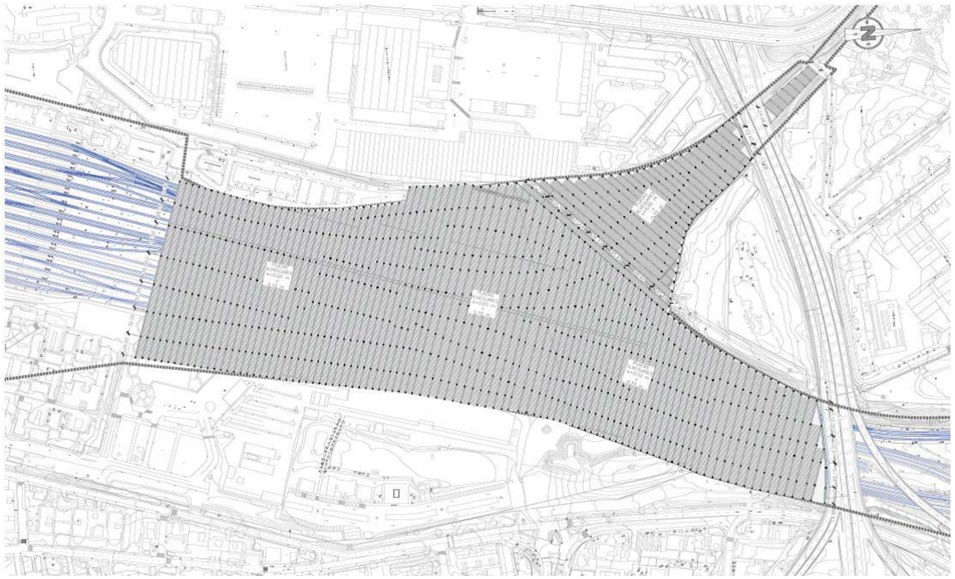
## South Area



The southern area is located at the south exit of the Chamartin Station and includes partial covering of the tracks that provide service to the station.

In this area, the structure has an almost rectangular shape, and consists of two rectangular pieces, one with a length of 310 m and an average width of 35 m, and one with a length of 40 m and an average width of 70 meters.

The proposed solution has a maximum span of 36.00m in the main direction. In the following sketches a continuous solution is shown, but as already noted, the isostatic solution was also valid.

The structure is formed basically by a series of prefabricated frames, perpendicular to the tracks and located every 8 or 10 m, formed by prefabricated beams resting on pier on piles, and on which prefabricated plates are placed with an additional compression layer.

The positioning of piers has been made in compliance with the horizontal clearances, and foreseeing the possible extension of the tracks in areas where it can be possible. The

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interferences with electrifications devices, post, catenary, contact lines, etc.. it is also avoided in order not to interfere with traffic rail operations.

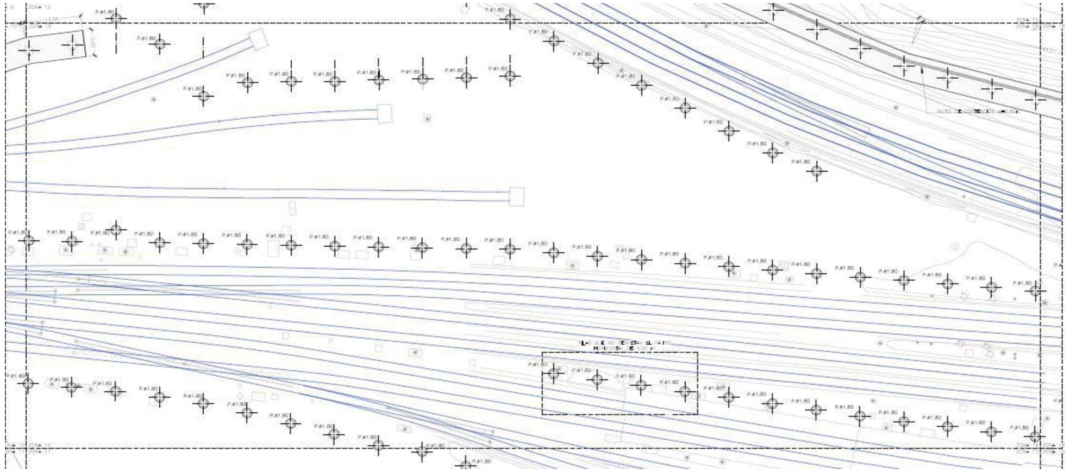
An expansion joint coinciding with the exchange zone width is arranged. Moreover, transverse expansion joint every 100m are also arranged. These joints are planned only at the level of the prefabricated plates. The following figures represent different cross sections of the current state and projected, in which it is assumed that the structure surpass all the electrification elements.

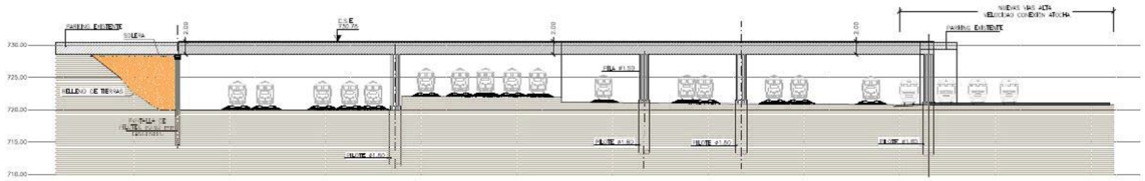
The structural solution thus consists of:

- Foundation through pier on pile. 1,80 pile diameter, diameter of the pier 1.50 meters. Maximum axial force up to 1,400 tons.

- Slurry walls by tangent piles of 60 cm. Concrete quality of HA-35 and reinforcement quantity of 120kg/m3.

- Prefabricated pre stress concrete deck. Main structural system by prefabricate beams of 2.70 meters





ESTRUCTURA SUR. SECCIÓN TRANSVERSAL 8. ESTADO PROYECTADO

total depth. The area of the main beam is approximately 2.40 m2, so its weight is 60.0 kN/m.

- Secondary structural system by prefabricated plates of 55 cm depth +10 cm compression layer.

Finally, to take advantage of the existing space over the exit of the 1 tunnel, some retrofitting and waterproofing actions must be undertaken.

**North Area**

The North zone is located just after the north exit of the Chamartin Station and includes the covering of a large amount of

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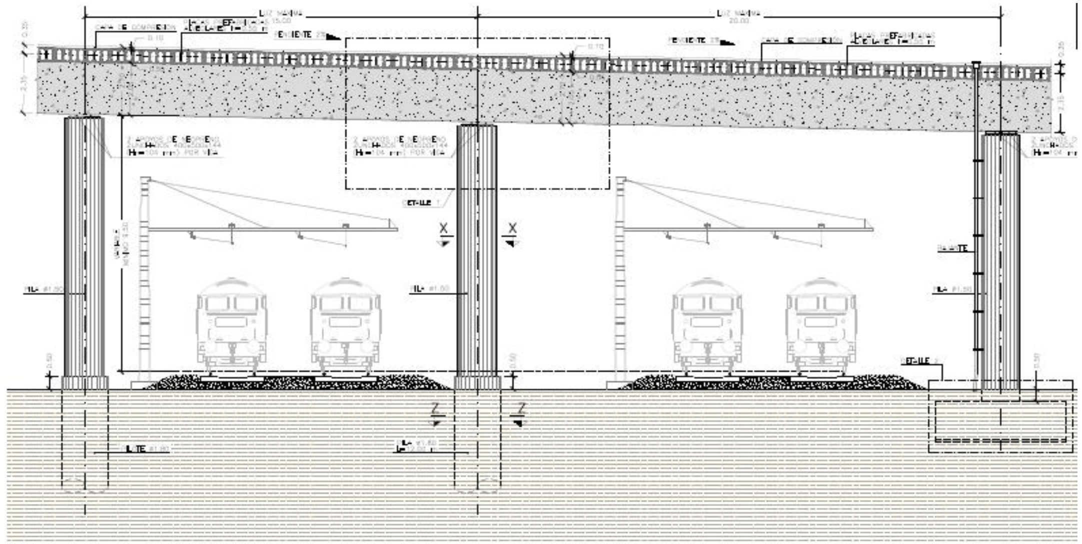
tracks and railway services of the station.
The structure has a polygonal shape with a bifurcation at its end. It has an approximate length of 835m and an average width of 252 meters, the bifurcation area has a length of approximately 300 m and a width varying from 15.00 to 245.00 meters. The total area covered reaches 200,000 sqm .

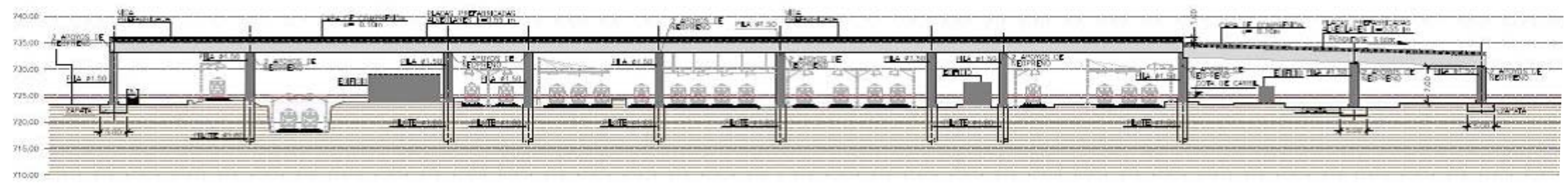
The location of the piers fitted between tracks, but respecting the minimum clearance of 4.00 meters, and the position and orientation of the main beams can be distinguished in the following figures. In this case, the only structural solution considered suitable was the continuous one.

In general, the structural solution is very similar to that chosen for the South Area. The structure is formed basically by a series of prefabricated frames, perpendicular to the tracks and located every 8 or 10 m, formed by prefabricated beams resting on pier on piles, and on which prefabricated plates are placed with an additional compression layer.

Just like in the south, the positioning of piers has been made in compliance with the horizontal clearances, and foreseeing the possible extension of the tracks in areas where it can be possible. The interferences with electrifications devices, post, catenary, contact lines, etc.. are also avoided in order not to interfere with traffic rail operations.

As it is a more irregular structure in plan view, expansion joints have been strategically





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located in order to disconnect the behavior of different areas with different frames orientation.

Moreover, transverse expansion joint every 100m are also arranged. These joints are planned only at the level of the prefabricated plates.

**Construction process**

Because of the enormous extent of areas to be treated and covered it is difficult to speak of a unique construction process. But it is important to point out which is the general construction sequence adopted.

This construction sequence aims to minimize the impact on rail traffic, avoiding superficial and large foundations by executing piles, avoiding falsework and formwork using prefabricated systems and simplifying construction by modulating beams and prefabricated plates.

The construction process comprises the following phases:

1. Execution of piers on piles

Firstly, piles of 1.80 m diameter are executed (a pile must be run every night; many of them must be done using drilling equipment and cranes from tracks. Secondly, the following night, prefabricated piers of 1.80 m diameter are placed. The connection is made through a Peikko or equivalent system that avoids the need for pile caps between piers and piles.

2. Placing of prefabricated beams

Then the prefabricated beams are placed in their final position on neoprene supports. One of the most important aspects of this stage is the auxiliary means that are necessary for placing these elements. These means depend on both the access to the site and the area to be built, as well as the availability of free space around.

In the southern area of Chamartin Station the total area to be covered has an average width of less than 40 m, situated at one side of the tracks, so lateral access to the site is guarantee, therefore, beams can be positioned by cranes outside the tracks.

However, in the north area the area to cover has an average width of 225 meters, making it impossible the positioning of the beams by cranes. Therefore, the assembly of beams will be made by overhead gantry.

This assembly system allows to industrialize the whole process, to speed up timing, and it is much safer not depend on weather conditions and the skill of the crane operator.

3. Placing the prefabricated plates

Once the beams are placed, the prefabricated plates are mounted by cranes from the already assembled structure, advancing on what has already been placed and without interfering with the railway traffic.

4. Placing the second phase prestressing continuity system.

Once, beams and plates are placed, the

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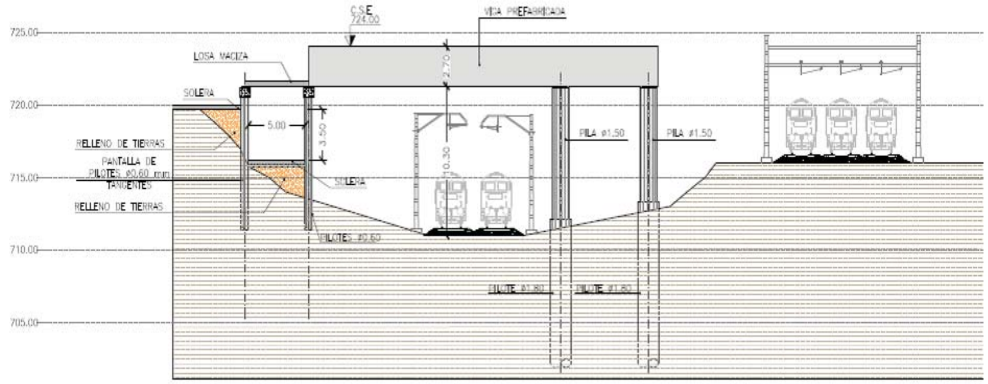
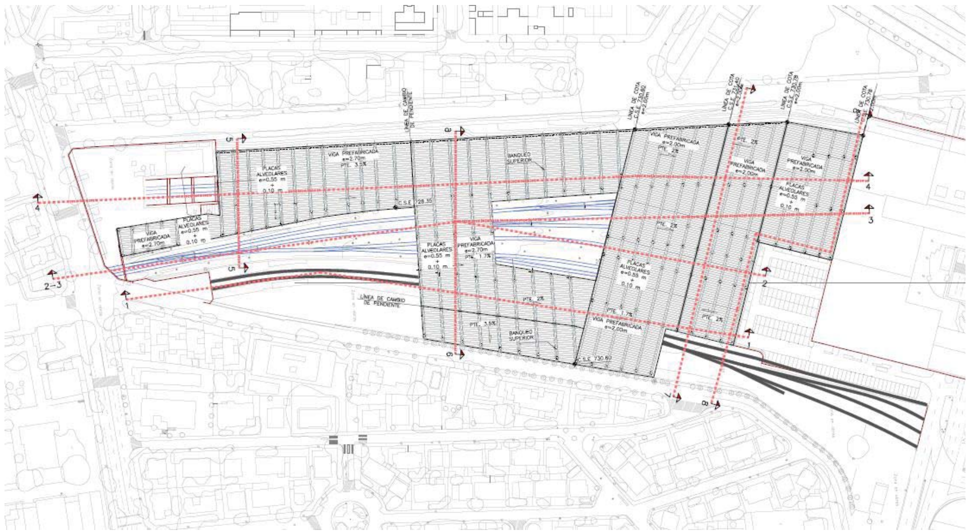



ESTRUCTURA SUR. SECCIÓN TRANSVERSAL 5. ESTADO PROYECTADO
ESCALA 1:400
(NOTA: TODAS LAS COTAS ESTÁN EN METROS)



second phase prestressing continuity system is settled. Its layout is essentially straight, allowing the prestressing from the upper face of the deck, thus, once again, all the work is done away from the tracks, without interfering with rail traffic.

With this prestressing system in two phases, the possibility of making continuous beams, reduce the total depth and weight of the beams.

5. Execution of compressive layer

Then, the following step is to concrete of the compressive layer is executed. Similarly to the previous phases, the concreting is performed from the upper face of the deck.

6. Prestresing of the second phase

Once, the necessary compression strength is achieved, cables are stressed. Therefore, a continuous beams system wil, take care of the rest of the dead and live loads.

7) Waterproofing

Finally, waterproofing of the deck is executed as well as the finished of the urbanization.

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