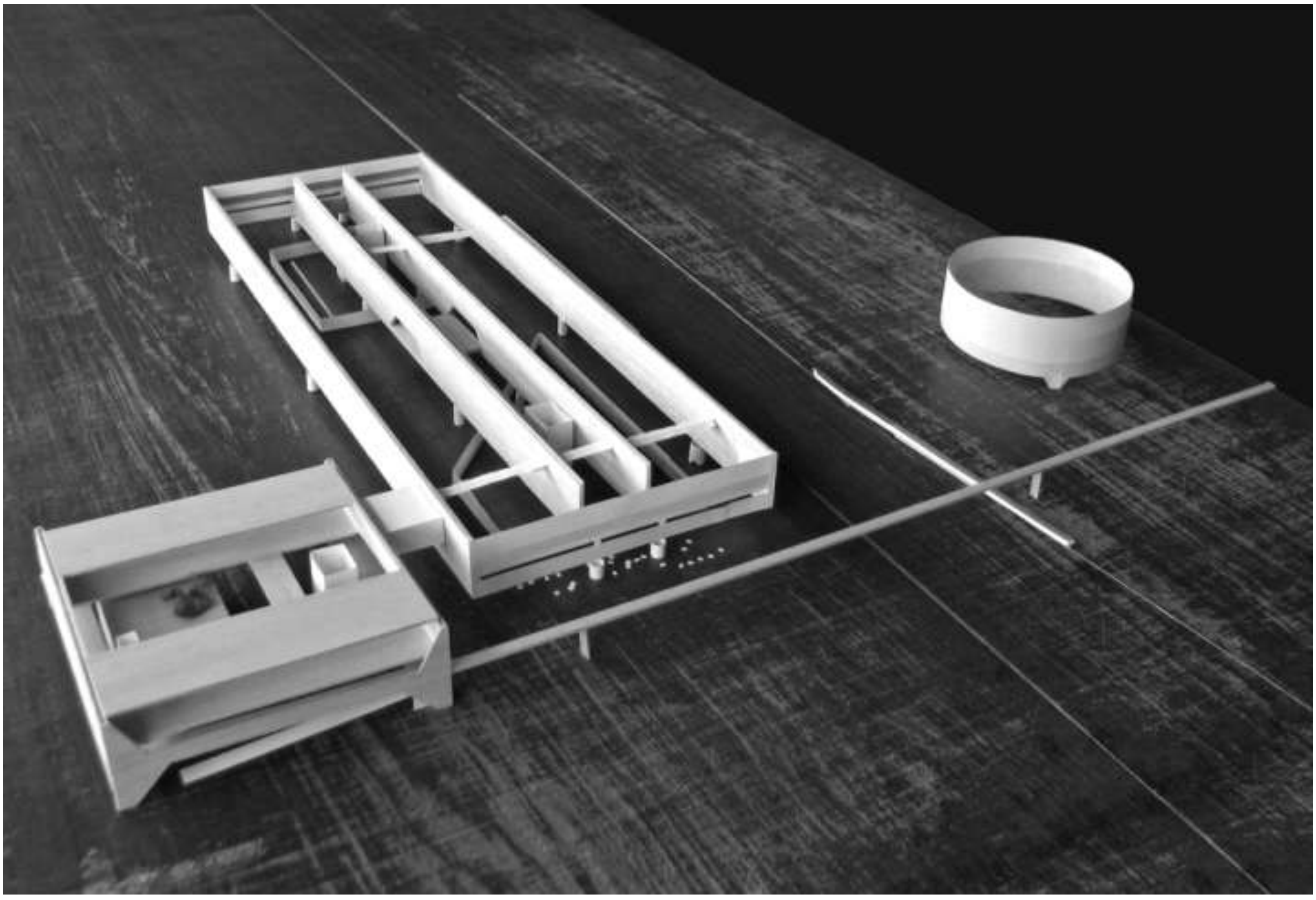
The Engineering of New Coach Museum



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The project was put into motion in late 2008 subsequent to an invitation made by the Portuguese government to architect Paulo Mendes da Rocha. The goal was to open the museum on 05 October 2010 as part of the celebrations involving the Centenary of the Republic. The New Coach Museum should guarantee the preservation of Portugal´s collection of coaches and the exhibition of the same to around 1,000,000 visitors a year.

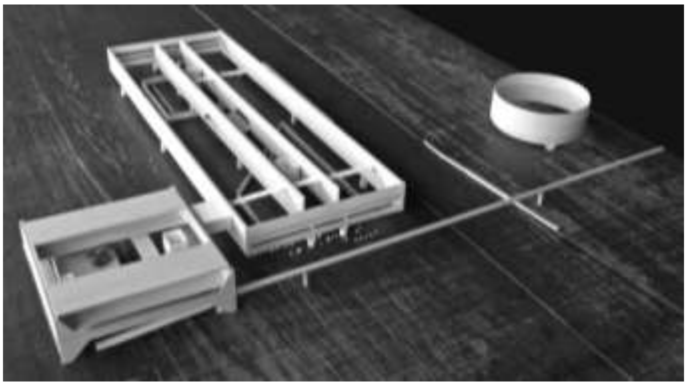
Paulo came to Portugal to see the location and get to know the Museum´s programme prior to returning to São Paulo. He returned to Lisbon two or three months later to present his ideas – his conception for the Museum was based on the idea of a "white chest" for storing the "treasure", most of which is Baroque and rich in ornamentation.

What the architect basically brought with him were photographs from his work portfolio and great certainty with regard to what he was proposing to do:

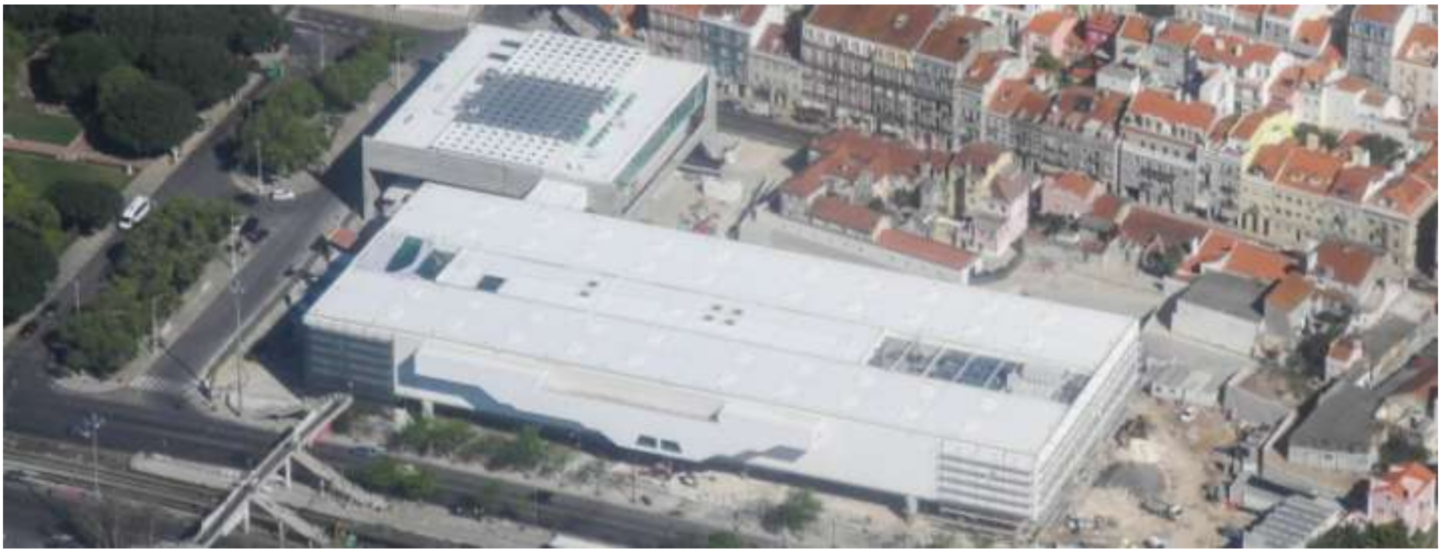
1. The Museum facilities – raised from the ground, with the workshops, a cafeteria and the Museum entrance on the ground floor;
2. The annex, connected to the Museum by means of a bridge, home to the museum management and a restaurant on a raised level, and an auditorium on the ground floor;
3. A pedestrian walkway linking Rua da Junqueira to the Belem Maritime Terminal;
4. The car park – a silo with a continuous ramp alongside the River Tagus, at the end of the pedestrian walkway;

The unique layout of the buildings and the aerial connection between the two creates a portico marking the entrance to the inner square, looking onto the buildings in Rua da Junqueira and promoting the revitalization of the same in the recreation of what used to be Rua do Cais da Alfandega. This layout emphasizes the relationship between the areas on different levels enhancing the activity of the passers-by, consolidating the return to the city of the entire plot of land and extending a warm invitation to visit to the museum itself. This basically conveys what the Museum really is according to the vision of architect Paulo Mendes da Rocha, a public place – "strictly protected and unpredictably open".

The proposal responded to the programme but expanded the scope of the same, corresponding to a comprehensive analysis of the location and of its possibilities and requirements, and focusing on the creation of a qualified public area.



With the exception of details, it is surprising how the initial proposal corresponds to the end result – all that differs is the upper walkway (construction of the same is due to begin in the near future) and the silo car park – rejected by the Lisbon City Council. The remainder is all there, just as Paulo had envisaged right at the beginning. Slightly smaller – due to budget restrictions – but with the same layout and implementation of the initial proposal. Throughout the process there was no prima donna-like stubbornness or submission to any kind of speciality - all the requirements of the building were dealt with using the simplicity of the original idea - to sum up, it was all extremely well planned.



Any 21st century building – but particularly a museum with the characteristics of the Coach Museum – serving to preserve a unique treasure and required to welcome 1,000,000 visitors a year – is a machine the efficiency and success of which depend both on the manner in which its components perform their function (without prejudice to the others) and its ability to feature rooms capable of surprising and inspiring us. This demand requires the architectural and constructive solution used to be capable of simultaneously meeting the needs and requirements of the different systems vital to the smooth running of the building.

Coming from Brazil – the land of ”visual concrete” – the building had been planned using this material. However, considering the 50-metre spans, the tight construction deadline involved, the landfills providing the foundations for the building, the seismic activity to be conducted and the need to implement complex and demanding environmental monitoring systems, we suggested switching to a lightweight construction system – a monolithic metal structure “fixed” in the centre and sliding on the peripheral supports and light plasterboard panel walls.

The proposed construction system thereby arose to complement the architectural solution, enabling us to reduce the mass of the building and optimise the cost of the foundations and vertical components, and, at the same time, guarantee the shortest possible construction period. However, due to several unexpected changes – the availability of land, transfer of the services implemented on the site, etc. – the deadline ceased to be a priority, but the remaining factors of the decision remained in force.

The option for the structure of the shell, featuring 46-metre longitudinal and 18 and 12-metre transverse beams, was a hyperstatic and redundant lattice structure with a three-dimensional profile, taking full advantage of the main structural elements such as the locking parts of the main structure in the other direction and making the most of all continuous surfaces and the greatest possible redistribution of stress, always striving for high levels of simplicity in assembly.

The large longitudinal walls of the shell house the main lattices, which take advantage of the considerable height of the building. These walls also house the great service distribution arteries connecting the Museum´s two technical areas located in the open spaces at the extremities of the top floor.

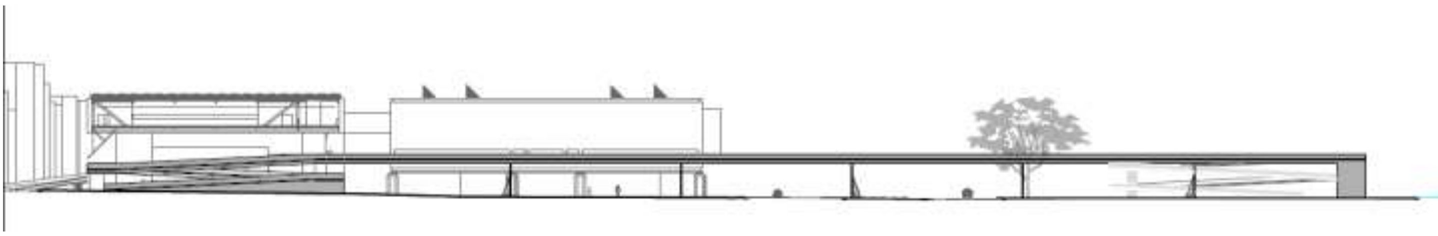
The architect thought of the annex as a covered building, partly empty, in which the concept of indoors and outdoors becomes confused due to the diverse views and environments it generates. A pre-stressed concrete portico structure supports two steel and glass boxes designed to house the management office and a restaurant. The auditorium occupies a concrete box on the ground floor.

The ramp connecting Rua da Junqueira to the upper walkway which will lead pedestrians to and from the Belém Maritime Terminal ends at this annex. It´s floor level – originally defined at 6.60 m – is equal to the Museum´s: it was a straight line almost 300 metres in length connecting the monument area with the riverside and the planned car park.

This passageway and the car park planned for 400 vehicles constitute a viable proposal for minimising the problem of parking in the monument area of Belem, currently packed with cars parked on the surface. The Lisbon City Council scrapped this part of the project, the funding of which would have been guaranteed by concession rights to the exploitation of the same.

What was intended for the upper passageway – now in compliance with REFER requirements (the most noteworthy feature of which is the 7.5 metre clearance over the railway line - around 8.1 m to the pavement) – was a simple pragmatic construction identifying it with the Museum. The plan was for 3 sets of 3 spans of around 30 metres each, with the decks composed of 3 parallel HE550A beams. The pillars are slender reinforced concrete slabs. The guardrails are identical to those of the Museum – solid pre-fabricated white concrete panels supported by metal uprights.

It should be pointed out that the construction of the Museum was conducted in strict compliance with the initial budget set by the client and accepted by the project team. The project has been concluded and is ready to open. As of the time of writing, the tender processes in relation to the works in connection with the exhibition project – vital for the opening of the Museum – and the construction of the overhead pedestrian walkway, had not been launched.



THE EXHIBITION PAVILION

The exhibition pavilion is designed to house the coaches to be transferred from the current museum and is located alongside Avenida da India. The 16.5-metre high building could be described simply as a white, opaque paving stone 126m x 48m x 12m in size supported by a 14 circular pillars 1.80m in diameter. The interior of this building is divided into 3 longitudinal aisles.

In addition to the raised floor forming the core of the Museum, the building features several complementary areas distributed on the ground floor and a small underground area.

The exhibition areas are located in the side aisles on the 1st floor and include two large permanent exhibition rooms with around 125 x 17.25 m² of floor area each and a double height ceiling (8.28m), marked by the continuous concrete paved floor, totally white walls and the white metal grate of the suspended ceiling, which at the same time as it closes all the infrastructure in the building, ensures one has a perception of its presence. The Museum´s longitudinal walls reveal the presence of a series of spans in the shape of the structural metal lattices, and in the case of the intermediary walls, the display windows built into the same.

In the central aisle between these two rooms is a series of areas making up a temporary exhibition room with around 215 m² of floor space and direct access to the entrance, a workshop area for daily maintenance housing the coach ramp, public toilets and the public thoroughfares linking the different areas and access to the emergency stairs also located in the central aisle.

The 2nd floor of around 1,380 m² total area is limited to the central aisle and comprises the technical areas where the exhibition area HVAC system equipment will be installed. In addition to these areas there is also an educational service room and a set of halls and passageways leading to an upper level with a more exclusive view of the exhibition areas and access to the outside terrace in the south wing with a view of the river.

These passageways also provide access to the overhead walkway to the annex building which museum staff will use to get to the administrative areas.

The need for the strict control of lighting in the exhibition areas means there are almost no openings to the outside. Just a small number of horizontal slits in each of the tops of the building and a few other openings meticulously placed along the longitudinal wings of the building. Skylights have been placed in the exhibition room roofs for the natural removal of smoke from these rooms.

The ground floor is divided into two independent modules, the entrance module and the reserved and service areas module of the Museum. The entrance module, which includes the store and cloakroom, is closed with full glass facades, creating an effect of continuity with the outside environment. Two large lifts with a capacity for 75 people and leading to the top floor exhibition areas are located here. The other module, facing the Museum entrance, features the ticket offices and public toilets.

The maintenance and restoration workshops are situated in the centre, accessed from the outside through a large gate to the reception foyer and a fumigation chamber. This area leads into a wide, open space containing the maintenance workshops, vehicle replacements and a ramp on which coaches and other items are raised to the exhibition room floors.

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Closed spaces with no exterior lighting are set aside for storing more sensitive items such as saddles and equestrian accessories, clothing, documents, paintings and other objects. Adjacent to the workshops and opposite the ticket offices are the service areas, with bathrooms, changing rooms and rest areas for museum personnel, offices, the curator´s room, and service lifts leading to the basement and upper floors. This upper western side of this area also includes a space for the exploitation of a cafeteria with an esplanade and which similar to the entrance module features full glass facades.

Underground floor -1 is for the exclusive use of technical and support compartments. It includes, among others, fire-fighting water reserves, supplies of drinking water and reused rainwater, technical areas for the installation of HVAC equipment, a generator, a transformer pole and waste storage.

In general, the floors are covered in concrete slabs finished with a surface hardener and mechanical troweling. The outer cladding of the pavilion facade is of the Knauf “Aquapanel” type ventilated curtain and is composed of cement panels, waterproof plasterboard panels, thermal insulation, rock wool and vapor barriers. The inside cladding of the facades is composed of plasterboard panels and thermo-acoustic insulation. The roof will be covered in a sandwich system composed of a lower structural plate, a layer of thermo-acoustic insulation and an outer profile of the Kalzip type.

Given the widespread presence of large spans, associated with concept of raised buildings, the project opted for the use of lightweight construction systems, evident not only the building´s main metal structure, but in the entire surroundings, the reduced thickness slabs of the exhibition room floors, the metal roof plating, and the inner and outer predominantly plasterboard walls.

THE ANNEX BUILDING

This building is full and partly empty, the highlights of which are the independent auditorium module at the bottom, and the objects hanging from the visual concrete structural porticos for the administrative and restaurant areas at the top, with glass facades adjacent to the triangular structural beams.

The interior of the building features a group of vertical and horizontal notifications, mostly public, all of which are in an outdoor environment although housed by the glass and metal central skylight.

The 8.5-metre high auditorium is located on the ground floor and has a capacity for 330 people. It is made of visual concrete painted on the outside.

This is an informal area for visitors to the Museum and for educational services support, with two large side gates to accommodate a horse-drawn coach.

Concrete is also predominant inside, where the walls are covered in pre-holed concrete panels, behind which the thermal insulation which will also serve as soundproofing will be laid.

The ceilings feature pre-fabricated concrete beams with a T-section, the floor base comprises granite cubes and the benches are made of pre-fabricated concrete. There is a water mirror on the roof.

The ground floor and part of the auditorium module also includes an area for a store to be leased out in the northern section, and public toilets and a reception area and information desk in the southern section.

Behind the 1st floor auditorium is a spacious terrace over Rua da Junqueira, which also serves as a link between the access ramps to the new pedestrian walkway and Rua do Cais da Alfandega Velha.

The 2nd floor is composed of the two metal “bridges” with 45-metre span triangular beams supported by visual concrete porticos.

The eastern “bridge” with its splendid view of the new Museum square and the water mirror on the lantern is used for purposes of administration, featuring rooms for administrative services, offices for the management and curators, a library, toilets, staff kitchen and rest areas.

The western “bridge” is located in a spacious area with a view of the entire monument area of Belem, and is intended to be leased out for the installation of a restaurant.

This area holds a kitchen, bar and toilets, and the remaining space is used for the preparation of meals.

Two metal walkways and concrete pavements form the link between the “bridges” and also provide access to the reinforced concrete blocks housing the emergency stairs and access lifts.

There is also a small technical area on the northern walkway.

The polished concrete paving, glass facades and suspended metal grate roofs provide continuity to the solutions used in the exhibition pavilion.

PEDESTRIAN AND CYCLIST PASSAGEWAY

The solution proposed for the pedestrian passageway preserves the concept of public space the entire project is based on.

The way to the north begins within the boundaries of the annex building over a set of 3-metre wide ramps which extend from the level of the square to the raised level of the deck, also providing direct access to the northern terrace of the auditorium from one of the intermediate landings. After crossing Avenida da India, the railway line and Avenida Brasília, the walkway runs down until it meets the ramps, dividing once again to gain access from the garden.

The levels of the raised deck are subject to the need to ensure a minimum of 7.5 metres clearance in the area crossing the railway tracks, and to the need to comply with the maximum regulatory inclinations.

In addition to the ramps at the two ends, intermediate access via lifts and stairs is also planned to provide access to Avenidas India and Brasil, as well as access to the platforms on both sides of the railway lines.

THE SQUARE

The square under development under the buildings is a single surface covered in granite cubes, occasionally interrupted by the building´s areas and features built at ground floor level.

Inclusion in the context of the surroundings involves solving the transitions between different levels, which in the most uneven area, the north, is achieved by installing a set of ramps and stairs, and which is achieved in the other areas with less unevenness by placing occasional smooth warps in the levels of the pavements.

The proposed solution is based on opening up the square as a public area, taking advantage of the permeability of the buildings at the level of the square and of the absence of any other type of barriers to the passing of pedestrians. Vehicle access, despite being possible and necessary for purposes of maintenance and loading and unloading, is however prohibited to the general public.

A road has been built alongside the southern side of the Museum to enable visitors to be driven right to the entrance and where buses may stop and park.

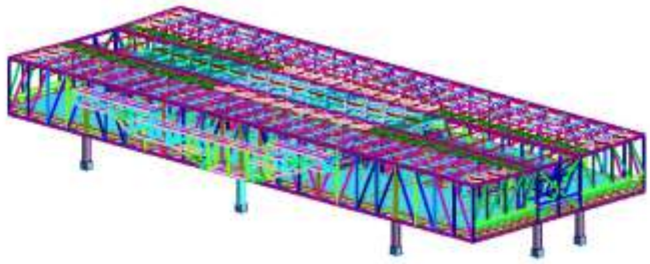
STRUCTURE

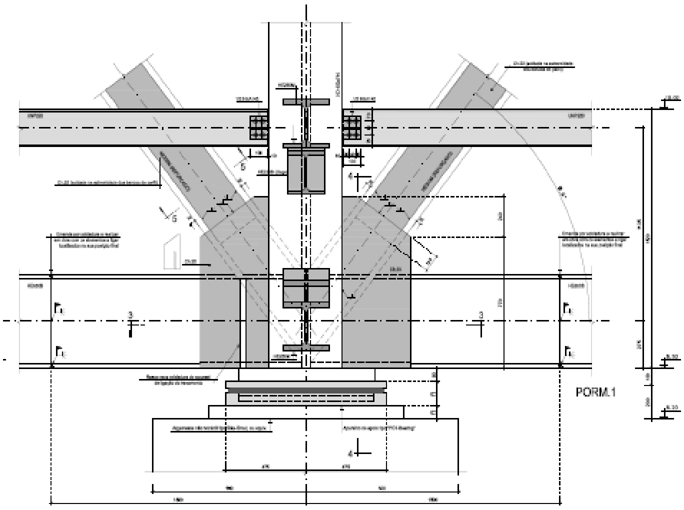
The early days of the project showed that the structure would assume a particularly relevant role in the design of the building, and which, furthermore, gives continuity to the roots of the work of architect Paulo Mendes da Rocha.

The development of the project has confirmed and expanded the idea that the role of the structure was relevant not only in relation to the shape, but also in relation to the contribution to the definition of finishes and architectural details, illustrated in the choice of visual reinforced concrete or metal structures both on the inside and outside of the building. A paradigmatic example of this situation is the case of the annex building, where in addition to the structure, in relation to finishes, only glass facades, the glass in the lanterns and the suspended metal grate ceilings were considered. In the case of the exhibition pavilion there is also the case of the cladding of the vertical facade blocks.

This factor resulted in the architects´ concepts for the project being kept private during the first phase, which ended up occurring naturally, as it was clear the ideas and expectations of both were synchronized from the very beginning. Thereafter and prior to the commencement of the real project work, the joint definition of the overall criteria to be complied with in the design of the buildings was achieved with ease, and which ended up being strictly imposed during the execution of the different phases of the project.

It now appears that after all the technical issues have been overcome and dealt with, that in general there are no differences when comparing the photomontages developed in the initial phase of the basic programme with the final result of the buildings constructed in the meanwhile, which basically illustrates the admirable expertise and experience provided, in particular by architect Paulo Mendes da Rocha, from the first sketches and ideas put forward in relation to the project.





Exhibition Pavilion – Main Structure

The main structure of the exhibition pavilion is a parallelepiped block 126 metres in length, 48 metres in width and 12 metres in height, supported by 14 circular pillars, each around 4.5 metres in height and with a diameter of 1.80m.

Such characteristics made the choice of a metallic structure almost obligatory, as only by ensuring structural lightness, and the lightness of the construction as a whole, could adding excess weight to the 14 support pillars be avoided.

The structure is made up of four principal large triangular beams, each around 12 metres in height, placed along the longitudinal walls of the aisles of the pavilion, which ensure the transfer, via the pillars, of the vertical loads applied to the building.

These beams, together with the structural elements that support the raised first floor and the roof level, create a lattice of resistant, perpendicular and interconnected planes ensuring the lateral stability of the elements of each of these planes and efficiently transfer horizontal force, whether caused by wind or earth tremors, to the pillars and central core.

The main beams in the intermediate alignment are set 12 metres apart and are supported by 4 pillars, forming 3 consecutive spans, each of 42 metres. The alignment beams of the longitudinal facades are 18 metres apart from the previous beams and provide double support, forming two intermediate spans, each of 42 metres and two overhanging end spans, each of 21 metres. At the top of these beams are transversal triangular beams, of the same height, which close off the pavilion. The upper and lower chords of these triangular beams use HEB550 profiles, which, in addition to their structural function, also play an architectural role, as the lattices at the top and edge mark the base and top of each the facades.

The columns and the diagonals are generally comprised of H type laminated profiles, allowing greater inertia to be directed along the plane of the triangular beams. The mounts attached to the pillars are of a HD400x744 profile, which, contrastingly, ensures greater perpendicular inertia along the plane of the lattices.

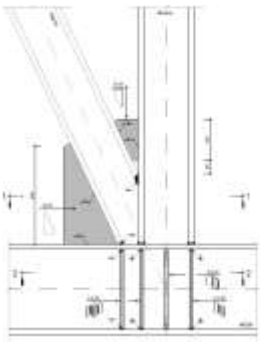
The lower chord of the beams is interrupted by these columns, which extend to the top of the pillars. For construction reasons it was necessary to limit the width of the columns and diagonals to 310mm, which meant that the columns were noticeably slim. To minimise this effect HEA100 profiles were used for the support purlins of the facade coverings, connected using metallic plates and providing continuity with the column zone, allowing a significant reduction in buckling length and taking advantage of one of the most effective parts of the column section.

The principal beam columns also ensure the transmission of loads by the external elements to which they are connected, such as in the case of the profiles of the lattice beams of the flooring, of the metallic beams of the intermediary flooring, of the second floor, of the lattice beams of the roof level and even of the metallic profiles of the outside terrace suspended from the structural beams of the south facade.

The joints between the main beams are welded. Elements are factory prepared and sent singly to the construction site, where they are subsequently welded together at the site using tables specially prepared for the task, in order to construct parts capable of being lifted from the yard together with the beams. Finally, to conclude the structure, these parts are placed in their final position and welded together, without overlooking the transverse elements necessary to ensure the stability of the construction during the different stages of assembly.

Exhibition Pavilion – First Floor Roof Slab

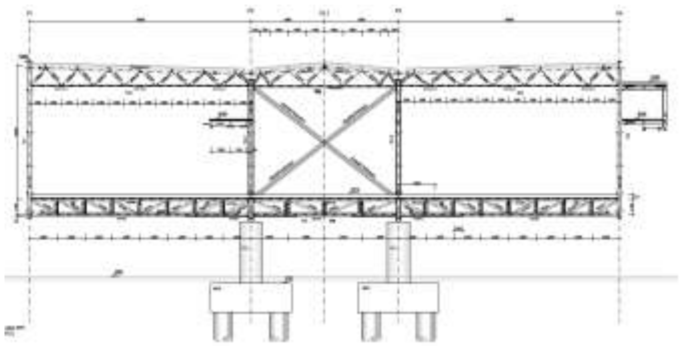
The first floor roof slab is located around 6.50 metres from the ground and is supported by a system of transverse triangular beams, positioned 5.25 metres apart, which receive the purlins, which are in general set 2.25 metres apart.

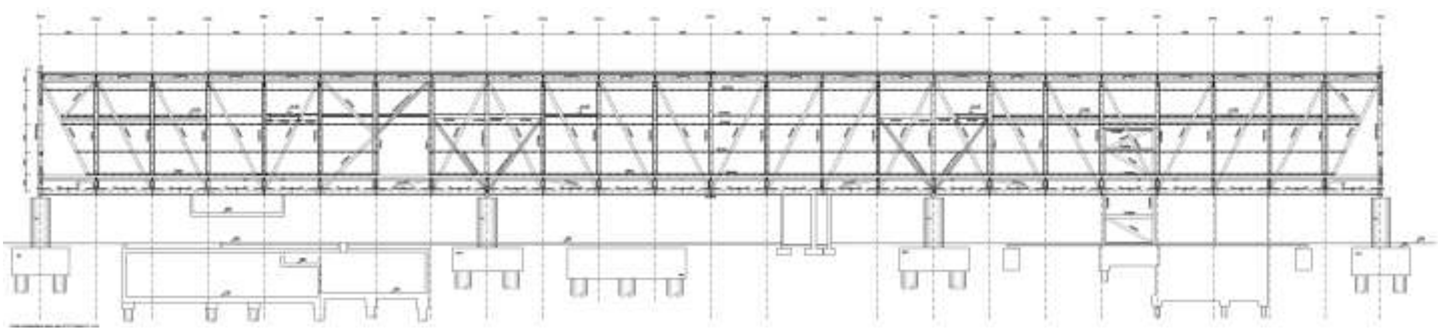


The transverse beams are supported by 4 large longitudinal beams, creating 3 spans, a middle span of 12m and two end spans of 18m each. These beams are made up of chords, columns and diagonals of type HEA and HEB, and are suspended continuously over intermediate supports. It was decided, for the end supports, to extend the lower chord of these lattices to the support device, taking advantage of the partial embedding and reducing buckling lengths of the main beam columns.

For the purlins, it was decided that IPE140 profiles anchored in two intermediate points by means of diagonals would be used, so creating 3 spans of 1.45m, 2.35m and 1.45m.

At the lower flange level of the transverse lattices, the anchors are locked using a set of 27 stays, which in the case of asymmetric loads, ensures a suitable reaction to counteract horizontal force transmitted by the anchors. At the level of the purlin, the upper flange will be locked to the corresponding plate, and for the long lower flange, in the surface zone above the anchors, it will be locked to the bending mold using 10 stays and welded directly onto the upper surface of the purlin flange.





The first floor slab itself has a unique set of characteristics that arise from the importance of creating a finished construction suitable for a diverse range of situations. In addition to structural functions, the project is required to meet the demands of thermal insulation, provide a final finish for the museum flooring, and allow for the embedding of pipes that circulate the radiant liquid that provides heating for the spaces of the building.

One of the fundamental premises established from the beginning was to avoid using expansion or construction joints throughout the exhibition hall area.

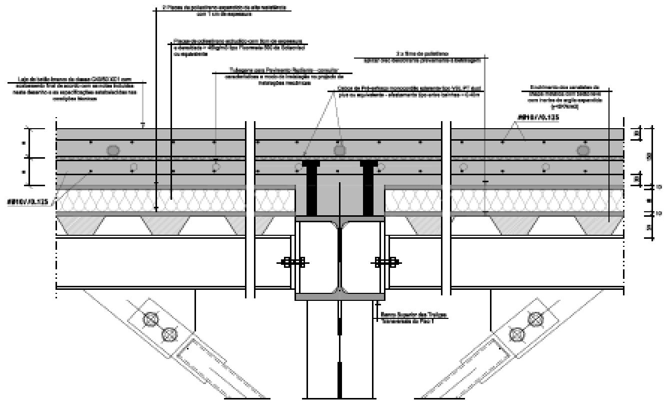
The level of finishing definition was tested during the project using various solutions, and included the taking of samples of concrete polished with different types of inerts and compositions.

The final choice was a white floor surface hardener trowelled onto a large slab of white concrete, which in addition to meeting aesthetic requirements, performs excellently as flooring material, especially in terms of resistance to wear and tear.

For a number of reasons, it was decided during the construction phase to manufacture a slab in grey concrete with surface hardener and final finish using lithium based sealant and subsequent polishing.

With this solution greater surface resistance and sealing was obtained and furthermore, final polishing can be performed at the end of construction, allowing the elimination, or at least the reduction, of unwanted marking to the flooring during the construction period.

The slab includes a contoured 1.5mm thick steel plate supported on purlins, and which receives the conduit filling of lightweight concrete of expanded clay, a joint-spacing layer, an 8cm thick layer of thermal insulation of expanded polystyrene and a further joint-spacing layer, onto which the 15cm concrete slab is cemented.



The under-floor heating tubing is embedded in the slab. In order to absorb horizontal load at floor level, it is suggested the same be connected to the central stair block and the main metal structure in the central third of the slab along an extension of 42 metres. The release of the salb in the two end thirds results in a need to reduce the stress due to shrinkage and thermal variations. For transverse seismic action, the end thirds of the balcony are cantilevered, allowing, via a diaphragm effect, the transmission of the horizontal actions to the fixed support of the intermediate pillars and also to the reinforced concrete core located in the E2 stairway.

In order to limit and control fissuring, the application of longitudinal and transvere pre-stressing is proposed, dimensioned to ensure a minimum residual compression of 1MPa for most situations. The pre-stressing adheres to “0.6” mono-chords in central metal sheaths, 0.40 metres apart.

In dynamic terms, the first floor slab of the exhibition pavilion is characterized by having initial natural frequencies of between 3 and 3.50Hz, within the critical range which would make the slab susceptible to uncomfortable levels of vibration.

Taking this into account, a number of studies were performed of the most recent scientific publications regarding the material, and it was concluded that despite the frequencies themselves falling within the critical range, and while the mobilised masses have significant values, this does not undermine adequate conditions of comfort.





Modo	Freq (Hz)
7	3.09
8	3.16
9	3.23
11	3.34
12	3.38
14	3.46

Exhibition pavilion – second floor and roof level

The second floor slabs appear only in the central aisle between two large longitudinal intermediate beams, and are composed of composite collaborative slabs that in the everyday areas have a thickness of 12cm, while in the technical areas, to cope with the weight of the equipment therein, and also to minimise and control the transmission of vibrations emitted by this equipment to the main structure, the slabs have a thickness of 20cm.

As in the exhibition rooms, the flooring here is finished in concrete using mechanical troweling and subsequent polishing following the prior application of lithium based sealant.

The metal support structure in this area is comprised of the principal metal beams, set 5.25 metres apart, resulting in a 12-metre gap between the large longitudinal beams, complemented by secondary profiles arranged orthogonally to support the floor slabs.

Metal walkways are also planned for this level, crossing the aisles of the exhibition rooms and connecting the northern annex of the building with the southern outdoor terrace. These walkways are comprised of pairs of HEB550 beams which, taking into account variations in behavior, will have a total span of 18 metres.

Exhibition pavilion – foundations

A solution of indirect foundations in the form of reinforced concrete piles molded into the ground is proposed for the main pillars and reinforced concrete cores, embedded in the volcanic complex with a W4-3 degree of alteration and F5-4 degree of fracturing, and whose embedded length varies according to load transmitted to the foundations.

The effective lengths of the piles are between 6 and 15 metres, with a diameter varying between 600mm and 1500mm. An acceptable tension of 400kPa at the level of the tip of the pile, and values of tangential tension of 75kPa along the length of the embedding were considered in the calculations of such dimensions.



Annex Building

The annex building encompasses the construction of two independent structures, the auditorium building and the administrative and restaurant building.

Annex – main structure

The principal structure is composed of a lattice of four frames in reinforced concrete, arranged orthogonally with axes arranged in a square with 45-metre sides, complemented by two large cores of reinforced concrete, where the vertical lifts and stairway are to be installed.

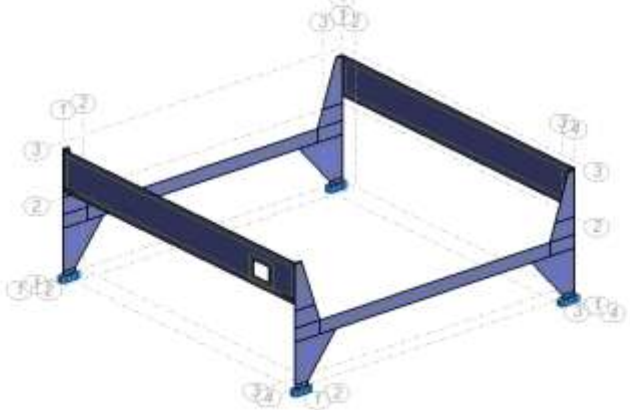
The north and south frames are equal and built on two columns joined at the ends, with a consistent thickness of 0.80m, and with dimensions along the surface of the portico varying between 2 metres at the joint with the foundations, increasing to a maximum of 8 metres at the connection with the intermediate beam, and reducing again to a minimum of 0.8 metres at the top.

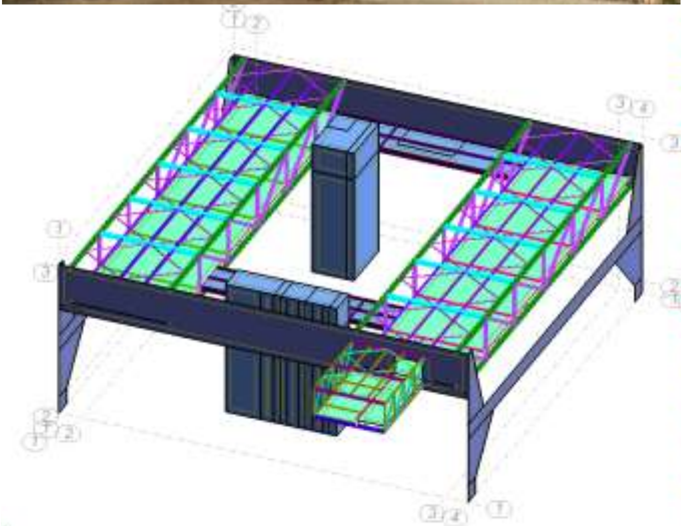
The intermediate beam is located approximately halfway up the column and connects the two pillars with each portico through a rectangular section of 0.80m x 1.80m.

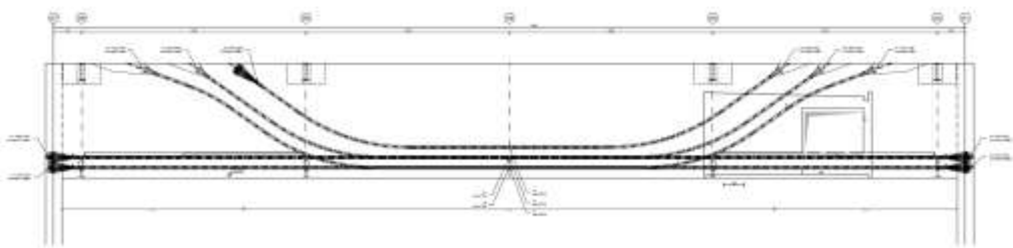
Perpendicular to the same and supported by the same columns are the north and south porticos comprising pre-stressed reinforced concrete beams 0.8 metres in width and 5.6 metres in height.

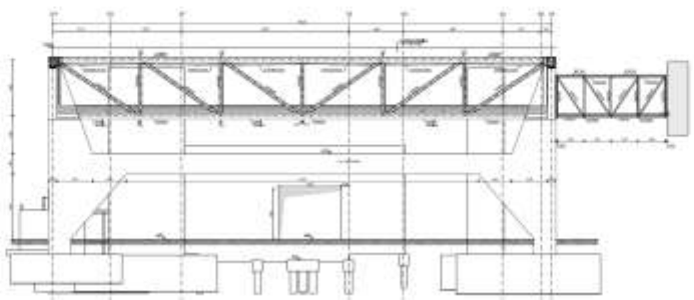
These porticos transfer most of the vertical load of the building to the foundations.

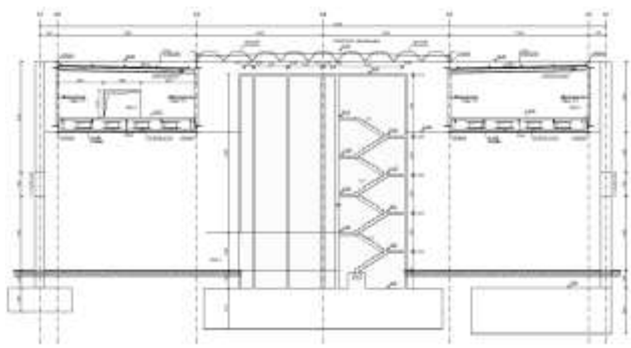
Additionally, and despite the reinforced concrete cores absorbing a large part of horizontal load caused by earth tremors and wind, the peripheral layout of these porticos plays a key role in the control of the rotational movement of the building.











Annex Building – restaurant and administrative sector

The areas designed for the restaurant and administrative services cover only one floor and respective roof and form a suspended parallelepiped block 45 metres in length, 11 metres in width and around 5 metres in height.

The extremities of these areas support the wall beams that form the east and west porticos, resulting in a total span of approximately 45 metres.

The main structure of each of these volumes is composed of two large triangular metal parallel beams 5.5 metres in height around 11 metres apart.

The structure of the floor is supported by these beams and is made up of welded reconstituted profiles placed perpendicular to the main beams and aligned in accordance with the position of the mass of these beams, which meet the longitudinal rafters on which the mixed floor slab is supported.

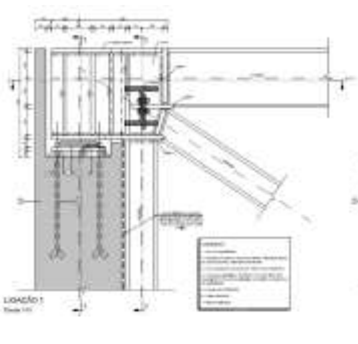
The structure of the roof is identical to that of the floor, although the profiles which comprise the same are obviously lighter, as it only has one metal plate covering.

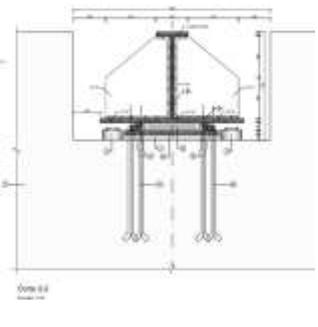
In addition to the structure which ensures the transmission of the gravity loads to the main beams, horizontal locking devices will be placed along the entire floor and roof structure to ensure the lateral locking of the main beams.

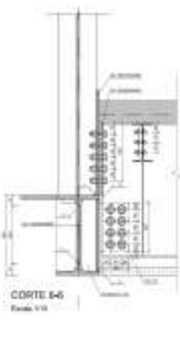
Each of the two suspended volumes is supported by the two large prestressed beams at 4 points only, located at the end of the large triangular beams.

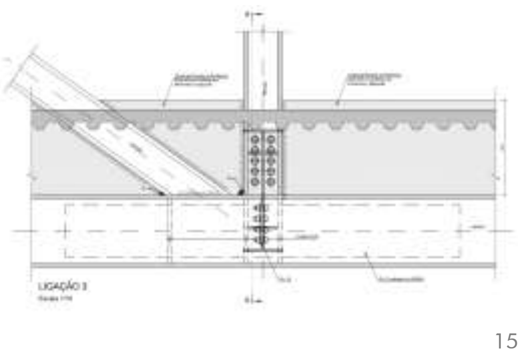
These support devices are located at the level of the upper chord and are materialised by neoprene support devices with controlled rigidity.

The entire vertical load is transmitted through these support devices. Due to earth tremors the horizontal actions act mainly at floor level, whereby in a longitudinal direction the same are transmitted partly by support devices and partly by a system of stops placed on the lower chord of the main inner beams.







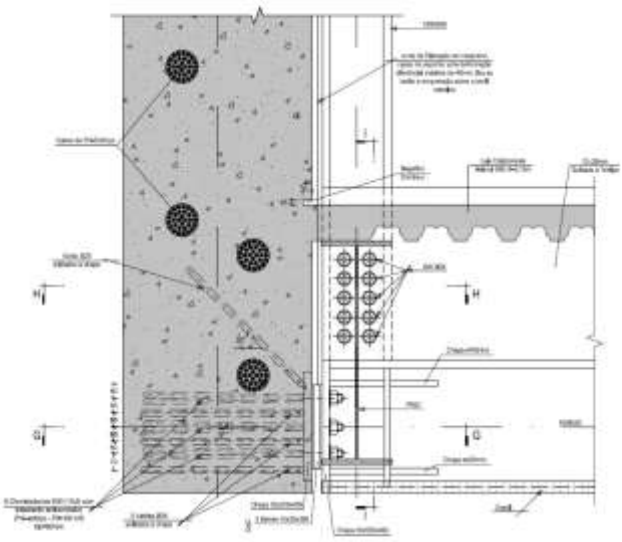


This stop system ensures, on the one hand, the quake is transmitted to the north or south portico in accordance with the direction of the action, and on the other, prevents the large triangular beams in the reinforced concrete porticos from embedding.

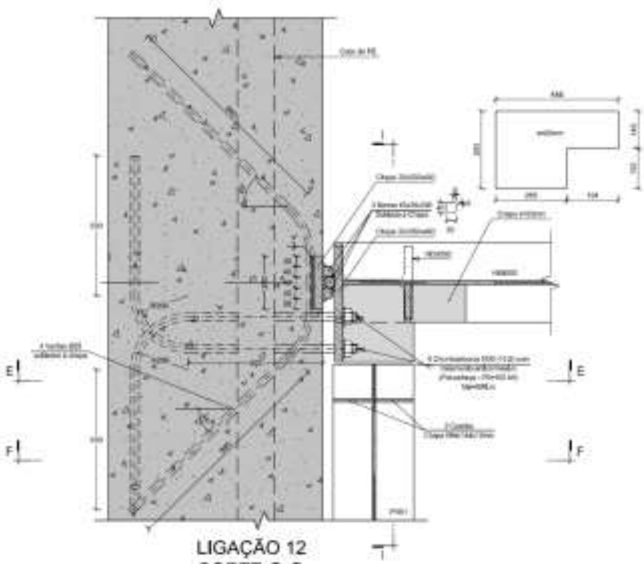
The horizontal forces acting at ground level in the transverse direction are transmitted by the same system of stops, in addition to the direct connection between the concrete slabs and the reinforced concrete porticos.

In order to prevent an undesirable concentration of tension in the more rigid areas next to the columns, this direct connection from the slab to the porticos is only present in the inner half of the floor.

It should be pointed out that the rigidity of the neoprene support devices ensures the transmission of horizontal forces by distortion for rapid action, as in the case of seismic action, and that the stress is not impeded for slow actions, as is the case of variations in temperature, thereby allowing for the distortion of the support device without the transmission of forces to the support element.



LIGAÇÃO 12
CORTE E-E
Escala 1/10

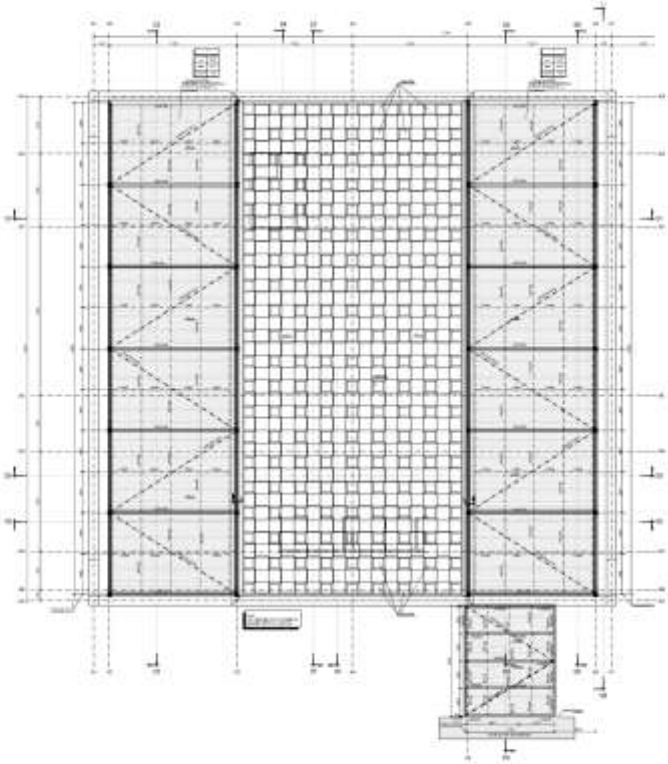


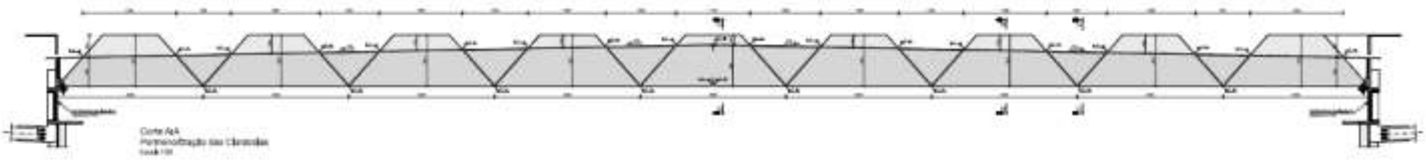
LIGAÇÃO 12
CORTE G-G
Escala 1/10

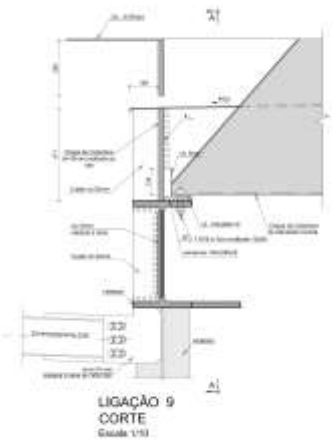
Annex Building - Skylight

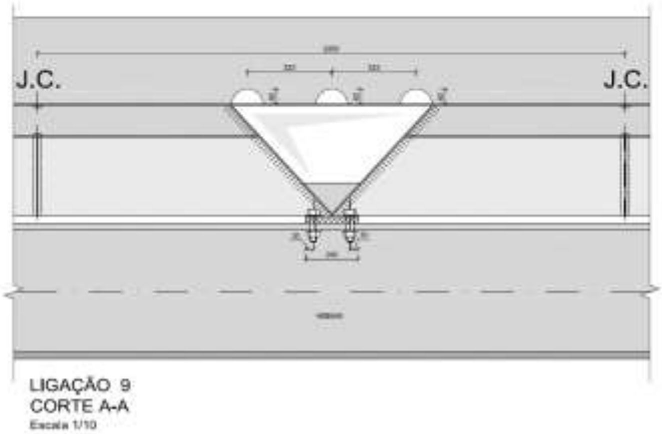
The execution of a metal plate roof is planned for between the restaurant and administrative area, made up of a set of V-shaped parallel beams with a maximum width of around 1.2 metres and 0.8 metres in height, in 6mm plate.

Another 6mm plate will be placed at the upper end of the "V", welded to the sides of the same and placed so as to form an angle of 2% to ensure rainwater drains away. The axes of these beams are set approximately 2.25 metres apart with other plates between the two, placed orthogonally and which reproduce the same type of V-shaped beam. This set of orthogonal beams allows for the creation of a group of skylights of an extremely interesting visual nature.



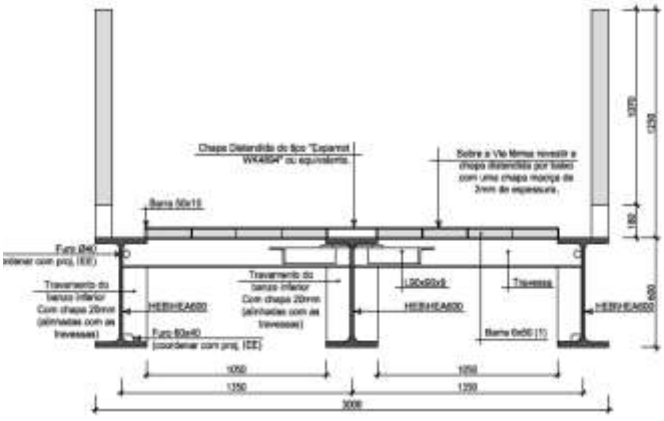






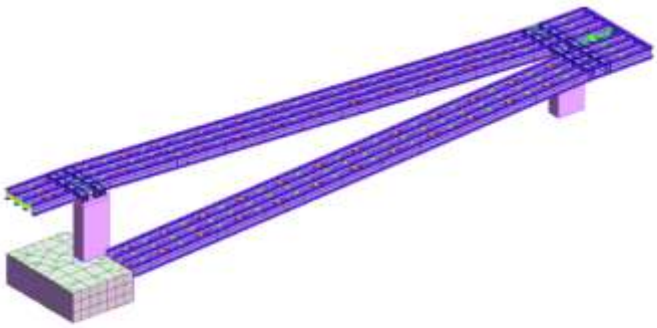
Pedestrian Walkway

The pedestrian walkway is made up of 3 structurally independent parts. To the north and still within the boundaries of the annex building are 3 ramps legs leading to the deck. The first leg of the ramp is made of reinforced concrete with a deactivated finish, whilst the others are made of a metal structure and form a span of around 37 metres, supported at the ends in brackets embedded in the concrete pillars in the gaps between the parallel ramp legs. The cross-section of the deck of these ramps is composed of 4 HEA600 profile longitudinal members joined with transverse members placed around 1.50 metres apart. The transverse rigidity of the deck is guaranteed by a triangulation system crossed with L90 x 90 x 9 angle brackets. It is coated in stretched steel plating.



CORTE TRANSVERSAL PELA ZONA COM 3 VIGAS LONGARINAS
TABULEIRO

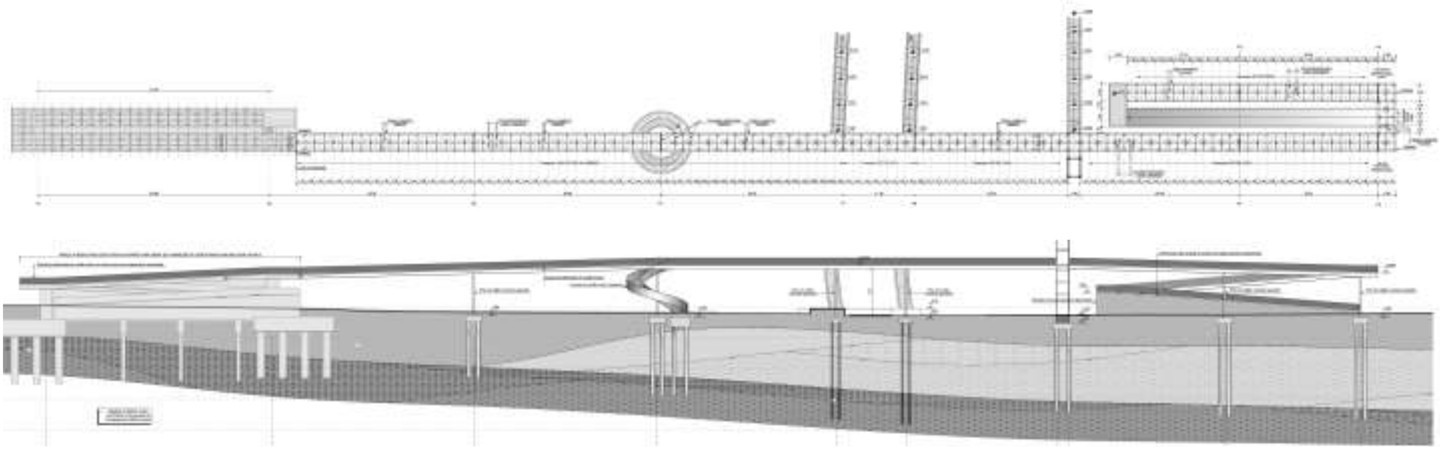
The transition to the deck includes a support device with an expansion joint which releases the deck´s longitudinal displacement. The deck features a cross-section of the same type, but with just 3 HEB600 profile longitudinal beams along 7 consecutive spans with a maximum length of around 30 metres. The support device is made of reinforced concrete slabs 3 x 0.25 metres in size embedded in the foundation.



In addition to the ramps there is direct access from the deck via stairs to the railway platform and the north side of Avenida da Índia and via lift and stairs to the south side of Avenida de Brasília.

The longitudinal locking of the deck is guaranteed basically by the structure of the lift and stairs module portico and by the installation of a vertical locking system in the form of triangular bars. The transverse locking of the deck is ensured by the rigidity of the slabs it lies on in this direction.

Similar to that which occurs in the north, the walkway arrives in the south through the access ramps in parallel groups. The departure ramp here Is also made of deactivated reinforced concrete, whilst the remainder are executed in a cross-section metal structure identical to that of the deck.



The access stairs to the north of Avenida da India are made of helical-shaped white visual concrete, connected to the deck by plating and anchor bolts embedded in the concrete.

This connection does not allow for relative displacement between the stairs and the deck, reason for which the stairs are sized in accordance with the corresponding settings in the longitudinal and transverse directions.

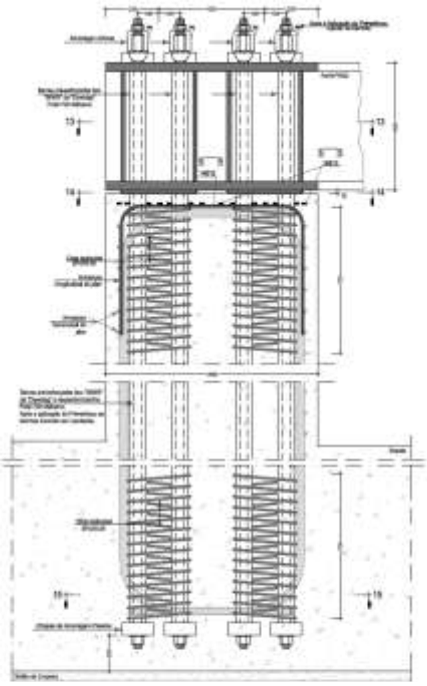
Aesthetic issues led to the choice of an extremely thin deck solution which resulted in the need to install damping devices to deal with fundamental structural vibrations.

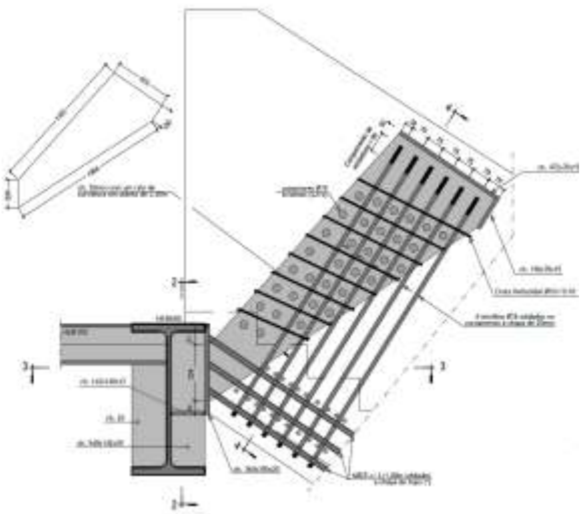
These devices are fitted under the deck between the longitudinal beams and will be calibrated based on dynamic analyses to be conducted after construction of the walkway.

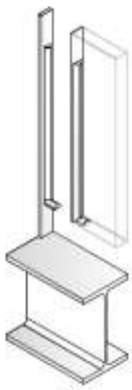
The choice of guardrails fell on prefabricated 80-millimetre thick white concrete panels with a maximum length of around 2.7 metres attached to the metal uprights welded to the stringers of the deck in advance.

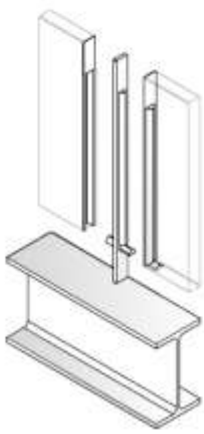
The similarity between the buildings is also reflected in the indirect foundation solution, normally in the form of reinforced concrete piles cast in the ground, set in solid basalt with a degree of alteration of W4-3 and F5-4.

Restrictions in relation to the area available to work in the railway platform area also demand the use of an indirect foundation solution using micropiles.









HYDRAULIC INSTALLATIONS

The hydraulic installations and equipment for the new Coach Museum building were designed in compliance with functional requirements, meeting standards of comfort, reliability and safety, using options which promote the sustainability of the new construction whenever possible.

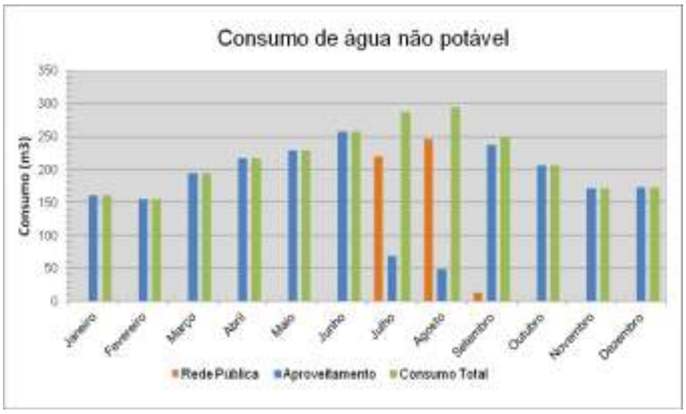
Water

With regard to water management and as a means of ensuring this resource is used in a more efficient and prudent manner, the project opted for a mixed supply system using potable water for human consumption only and implementing a system for the reuse of rainwater to supply all the devices capable of using water from other sources.

A rainwater reservoir will serve to flush toilets and irrigate outdoor facilities. This reservoir was built underground in order to protect the water stored in the same from temperature variation and light. The project includes a first-flush system to drain off the initial water, as the first few minutes of rain contain a level of pollution which is unsuitable for the reservoir, as is common knowledge. With regard to the distribution of water for toilet bowls and urinals in the supply line between raw and treated water, a filtering and disinfecting system is to be installed to prevent the risk of transmission of contaminants to the water distribution network.

The rainwater used in the system is collected on the roofs of the buildings and fed to the reservoir via a siphon network (Pluvia da Geberit), with the exception of the water from the outdoor pavements which is regarded as unsuitable for reuse. The entire system was designed in order to ensure the excess water from the reservoir flows straight into the public drainage network when full.

This system means EPAL only needs to supply water from July to September, equal to 18% of total consumption.



Sprinklers and water curtains

In relation to safety, specifically fire-fighting with water, and in addition to an automatic fire-fighting system, the building is equipped with a sprinkler and water curtain system backed up by a 260 m³ water reserve and two groups of autonomous pumps (one for the fire fighting system and the other for sprinklers and water curtains).

A wet-type sprinkler system will be installed on the ground floor of the exhibition pavilion in the workshops and support areas. This type of system is activated when the ampoule in the sprinkler reaches a pre-established temperature.

Due to the specific nature and value of the works on display in the exhibition areas of the Museum, it was decided to install a double-interlock pre-action sprinkler system. This prevents accidental damage caused by water from both the piping system and the sprinklers. Two events are necessary for the water to be released: an alarm activated by the fire sensors and a sprinkler opening. Thus, if the alarm is activated but the sprinkler fails to open, the water will not enter the piping system nor reach the sprinklers. If a sprinkler opens but there is no alarm, the water does not enter the system either.

An instantaneous flooding system of the water curtain type is due to be installed on the 2nd floor of the annex building, comprising a series of open sprinklers capable of cooling the structure of the facade, which due to architectural issues contains no other protection against fire.

This system is made up of a piece of metal piping placed on the inside of the upper structure where the full cone nozzles are placed needed to ensure the formation of a uniform curtain of water.

ELECTRICAL, TELECOMMUNICATIONS AND SECURITY INSTALLATIONS

The approach in relation to the project for the electrical, telecommunications and security installations was focused on adhering to the framework of excellence afforded to the building, whereby technical rigour, innovation, the optimization of the systems, and, particularly, integration with the architecture were the maximum constraints

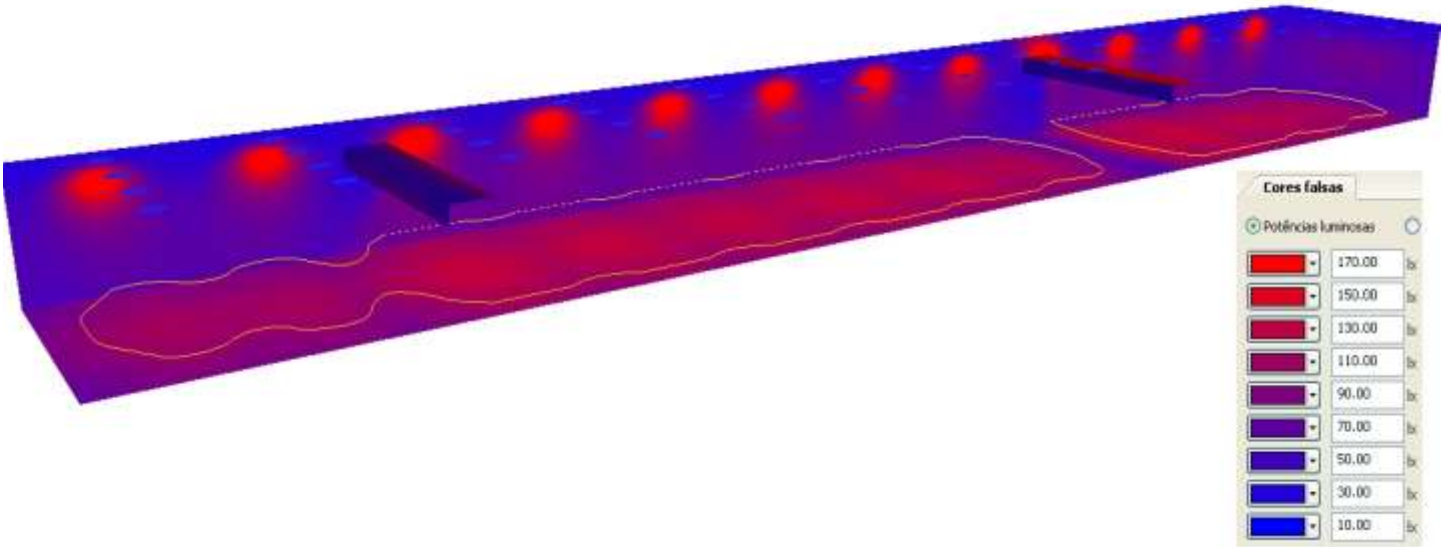
It should be noted that due to the architecture the different elements of the technical installations were exposed, which required particular care in the development of the routes and in the design of the systems with the aim of obtaining an attractive and safe end result. In light of the number of networks planned for the overall area, a colour code was established to facilitate the identification of the different networks, each in accordance with its speciality:

- Orange: Electrical installations and equipment;
- White: Mechanical installations and equipment;
- Red: Fire fighting installations;
- Black: Hydraulic installations;

The majority of the false ceilings are closed off with a lower metal grate with a 10cm x 10cm mesh, the main purpose of this grate being to delimit the area dedicated to infrastructure and to obtain an appearance of continuity. With this in mind the overall lighting solution involved the installation of a polycarbonate box over the industrial-type light grill, which in addition to high IP also reduces maintenance requirements, with a high-performance reflector fitted with T5-HO (high-output) bulbs and electronic ballast.

With regard to the exhibition rooms, and given the coaches are highly sensitive to UV radiation, overall lighting of around 100-150 lux was defined for these areas, backed up by a set of projectors equipped with appropriate filters and a globe system with an adjustable focus ensuring objects can be viewed with high levels of accuracy at considerable distances.

A demountable suspended system was created on which to hang the light projectors and other equipment which due to conceptual needs may not be placed above the grate (such as sound speakers, video projectors, etc), and ensuring the easy repositioning of any of the equipment on the grate.



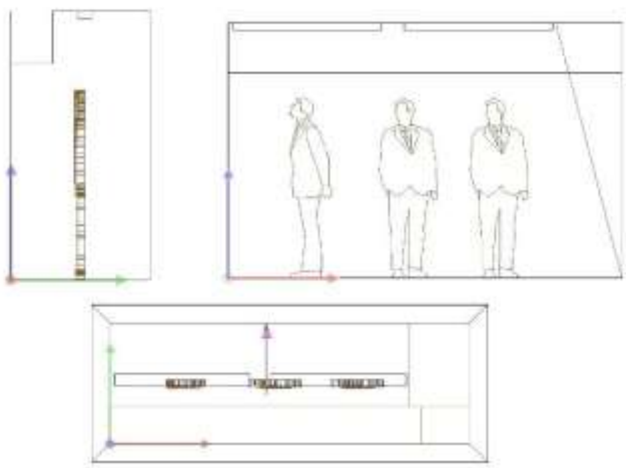
Combining constructive issues with the widths needed for the installation of ventilation ducts and other infrastructure it was decided to use false indoor walls of a considerable thickness to house the different technical infrastructure.

These walls are used to place larger equipment such as electrical switchboards and certain local power supply and command equipment, in addition to the installation of the Museum display windows lit on the inside by adjustable fluorescent LED lamps.

The design of the lifts, with a special focus on the two main lifts, capable of transporting 65 people on each trip was based on the idea that the same represent the “coach of the 21st century”, transforming the trip into a first exhibition of the Museum´s installations through an opening in the lifts´ beams, providing a view of the inside of the “false ceiling”.

The telecommunications project involved the creation of a structured network of optic fiber and category 6 UTP cable covering the entire area, thereby ensuring simple alterations may be made at any time, as was proposed for the Museum content presented using an array of multi-media equipment, the location of which is easily adaptable as they use centralised solutions in the servers.

Given the value of the collection on display, in addition to the experience of the existing museum, the project in relation to safety involved the implementation of a parameterisable CCTV system to guarantee both the monitoring of visitors and intruders, as well as the continuous recording of images of the different areas of the building. The dome type CCTV cameras with varifocal HD lenses in the exhibition rooms ensure the definition of a perimeter around a certain object (a coach for example!), which is proposed to be coincident with the elements of the lettering of the Museum project, and if this virtual barrier should be breached an automatic alarm will sound in the security room. The implementation of this system will reduce the need for local surveillance, in addition to optimising remote surveillance.



MECHANICAL INSTALLATIONS

The current National Coach Museum in Lisbon "preserves one of the most important and valuable collections of its type in the world" (quoting Simonetta Luz Afonso).

The purpose of a museum is to preserve historical artifacts, materials and information for future generations, in addition to providing present generations with access to that heritage and making the same enjoyable.

The HVAC systems play an important role in achieving the aforementioned goals, as they may help minimise the degradation of the treasure, but on the other hand if they are incorrectly set in relation to temperature and relative humidity they may help accelerate the degradation of the same.

Different types of materials require different optimum levels of relative humidity for purposes of preservation. Collections with different types of objects and materials therefore require commitment with regard to the level of relative humidity to be guaranteed. on the other hand, in the case of collections which have never been kept in a controlled temperature environment, excessive control of those parameters may even be counterproductive.

The idea of the Mechanical Installations and Equipment Project – HVAC – is to propose solutions which enable the new museum to be equipped with environmental treatment systems which provide conditions of comfort in the different situations of use, but also the specific thermo-hygrometric conditions for the conservation of the treasure, based on a commitment to the preservation of the treasure/human comfort in the display, storage and repair areas, the thermal comfort of the auditorium, areas providing access to the museum, administrative areas, the commercial and restaurant areas, as well as ensuring the normal and emergency ventilation of areas requiring the same, in addition to the production of hot sanitary water in accordance with the needs established. Always taking into consideration the optimisation of energy and the associated exploitation costs.

HVAC Systems

The conception of the environmental treatment systems aims to respond to the diversity of thermal issues arising from the different areas comprising the building, such as: exhibition rooms, storage rooms, restoration rooms/workshops, auditorium, administrative areas and restaurants.

The monitoring of relative humidity in museums is important and aims to ensure the material:

- does not absorb or cause the condensation of water which might accelerate adverse chemical reactions or microbiological attacks;
- does not dehydrate, losing mechanical resistance and/or flexibility.

The degree of deterioration of the material is not only a result of the relative humidity level, but also of the frequency and cycle of variation of the same.

As the ideal values of the parameters, temperature and relative humidity, are differentiated in accordance with the materials to be preserved, and, furthermore, are not always consensual, it is vital the owner of the work and/or the curator of the collection declare the values of the binomial temperature/relative humidity acceptable for the exhibition, restoration and storage areas in the Coach Museum, and the different solutions proposed and commitments assumed, as this is essential not only for the validation of the costs associated with the HVAC systems, but also for those associated with the architecture and other specialities, due the impact alterations to those factors could cause.

Most artifacts are comfortable in conditions of relative humidity of between 30% and 60%, provided the variation between those extremes is gradual, that is, over more than several weeks. It should be pointed out that the aforementioned values are perfectly compatible with human comfort.

On the other hand, extremely rigorous monitoring of environmental conditions, particularly relative humidity, involves extremely high associated costs, both in terms of initial investment and above all with regard to future exploitation costs.

Reason for which we propose certain commitment in the sense of optimising the initial investment/future exploitation cost ratio, without, however, neglecting the objectives the HVAC project is aimed at: preservation of the treasure, thermal comfort and quality of the indoor air.

The systems are designed to an ideal scale and with a focus on centralization and the appropriate scaling of thermal requirements, both heat and cold, and a thorough selection geared to energy efficiency and a harmless environment.

The functional organisation of the buildings is taken into due consideration, ensuring an appropriate order of importance of the levels of environmental treatment, and also in a perspective of simple running and maintenance.

Energy Systems

The energy systems involve the control of temperature and relative humidity requirements, the balance in relation to the thermal loads of heating and cooling, in addition to the specific nature of the exploitation of the areas.

As a base solution we propose the use of systems for the production of chilled and heated water, commonly known as heat pumps, air condensers, of the air/water type.

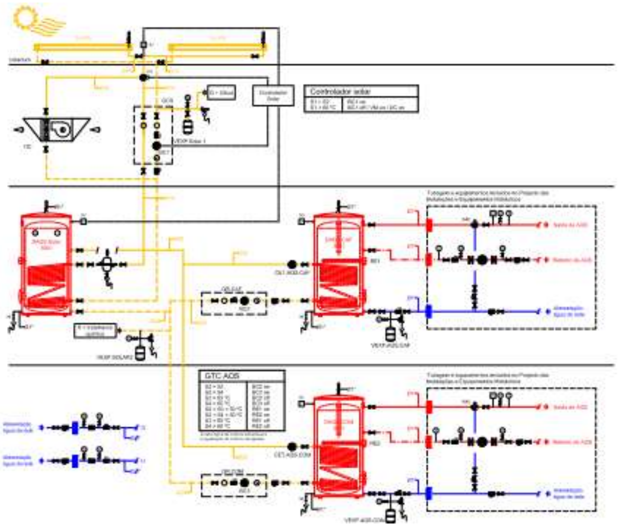
In light of the different uses, both temporal and functional, and the possibility of exploitation by third parties, eight autonomous heat pumps with completely different power capacities are to be used. The most powerful are intended for the environmental treatment of the Exhibition Pavilion, with the exception of the cafeteria and reservoirs which will use another small-scale heat pump. The other four heat pumps are smaller and are intended for the auditorium, the administrative area, the restaurant and the store in the annex building.

In the case of the two heat pumps assigned to the Exhibition Pavilion, and taking into account we are dealing with a building containing large areas and demanding requirements in relation to the control of relative humidity, heating needs exist throughout the year, although they may be residual in the cooler period, we advocate the recovery of hot thermal energy rejected from the cooling of the chiller-type heat pump condenser.

Inversely, and due to the same need for controlling relative humidity and possible cooling needs even in winter, when the heat pump is operating on heating mode, the cold thermal energy rejected from the heating of the evaporator is also subject to recovery, thereby increasing the overall efficiency of the energy system.

The heat pumps, in conjunction with the other equipment, promote the heating and cooling of the environment and the dehumidification of the air, in addition to the reheating of the air in cooler periods.

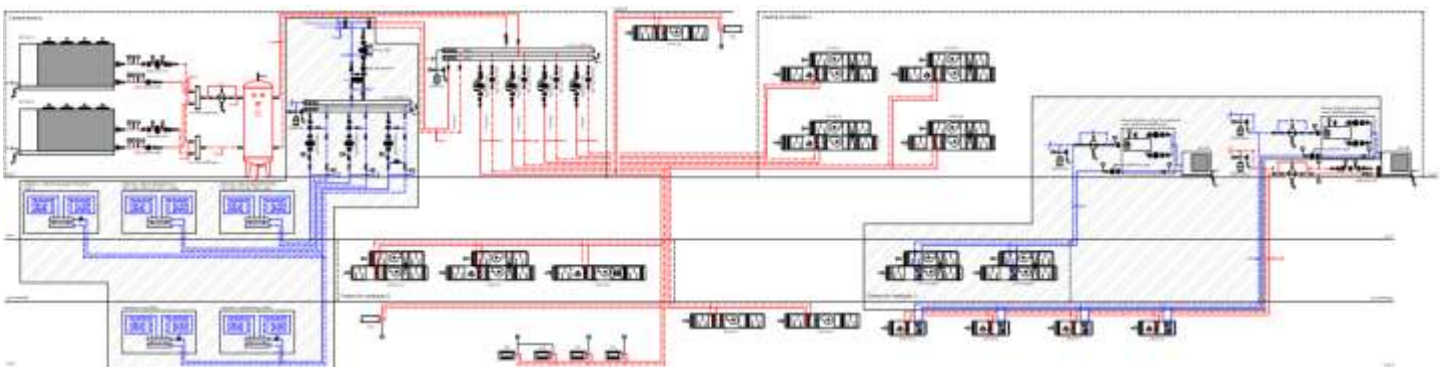
Solar energy is used to prepare domestic hot water for consumption using thermal solar panels in accordance with national legislation, the RSECE, and the most recent European Directive in relation to the targets to be achieved with regard to the use of renewable energy.



Environmental Treatment Systems

The environmental treatment systems are designed in an integral manner aiming at energy efficiency and sustainability, minimising the negative impact of the same on the environment so as to promote:

- the correct temperature, relative humidity and degree of filtering conditions for both human thermal comfort and the preservation of the treasure.
- the quality of the indoor air, that is, guaranteeing efficient ventilation.



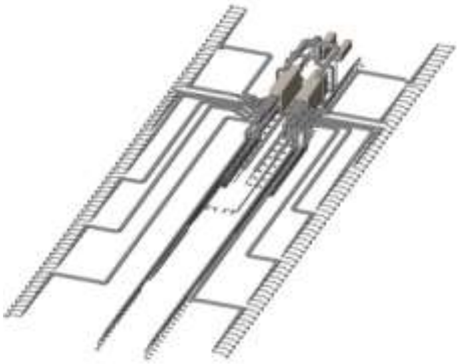
Above all, it is vital to simplify the solutions and optimise the technical/financial ratio, which will be reflected both in a reduction in initial investment and, particularly, in a reduction in future energy consumption and exploitation costs.

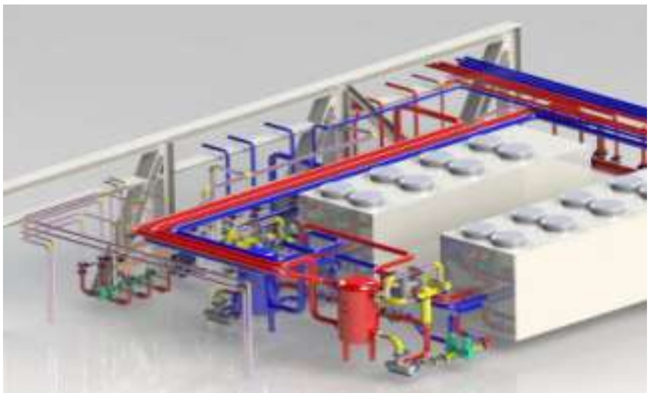
Without going into exhaustive details of the systems in question, there follows a summary of the solutions designed for the most important areas of the building.

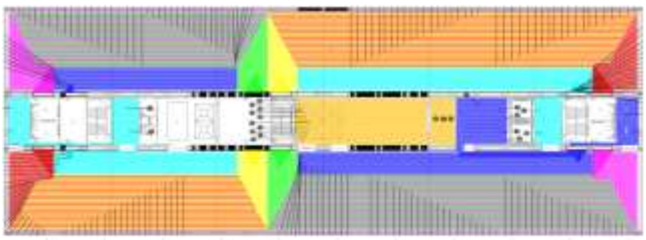
Exhibition Areas

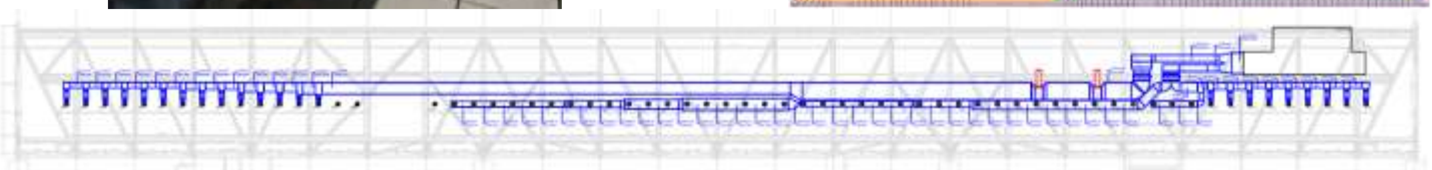
in light of the geometry of the rooms and particularly the considerable height of the ceilings, the environmental treatment is guaranteed together with radiant floors and specific air treatment units, both operating at temperatures extremely close to the set-point temperatures, reducing the thermal stress of the material on display.

That combination associated with the insufflations of air to a relatively low level allows for the creation of a volume control where the conditions of comfort and not the total volume of the areas are guaranteed.





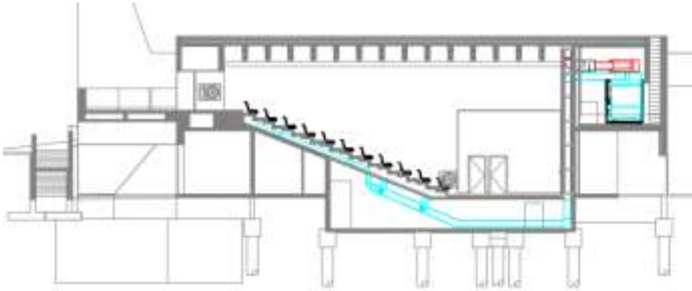




Auditorium

The environmental treatment is guaranteed by a solution of the displacement type taking advantage of the transfer of loads by natural convection to unoccupied upper levels.

The insufflation of thermally treated air takes place under the chairs at a very low speed and at a low temperature gradient, guaranteeing the quality of the indoor air and the removal of the thermal load, the extraction being conducted at high levels.



Administrative area and store

The insufflation of the air is once again thermally treated, guaranteeing the quality of the indoor air and local terminal units for the removal of the thermal load.

Restoration areas and the cafeteria

Heat pumps in association with fresh air treatment units, guaranteeing the flow of fresh air needed for each area due to issues of hygiene and the removal of thermal loads.

Specific ventilation systems are also planned, thereby guaranteeing the quality of the indoor air, once again in the form of extractors located in areas generating large amounts of pollutants, such as the kitchen and cafeteria.

Control of the Installations

A centralized technical management system (GTC) will be used to monitor the installations of the New Coach Museum. The use of a GTC ensures the adaptation of systems in time to the building´s real needs.

This may be rephrased as the more efficient use of energy and a reduction in wasted resources.

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Project:	**Architecture:**	**PMR/MMBB/BAKGORDON**
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