

## FORTE DA CASA FOOTBRIDGE

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### Summary

This paper presents the conception and general design of a pedestrian bridge currently under construction in Forte da Casa, a residential area just north of Lisbon, Portugal. This bridge is located in a complex and quite uninteresting urban area and connects the “Forte da Casa” residential district to the Tagus Estuary Riverside Park. Hence it was designed as a single gesture materialized in a straight line that minimizes complexity and reduces the impact on the clean horizon of the river Tagus plain.

**Keywords:** international competition; aesthetics; structural concepts.

### 1. Introduction

The Forte da Casa Footbridge is currently under construction and it is expected to be finished and open for use in mid-spring 2014. The solution was developed by “MXTstudio Architects” and “Adão da Fonseca - Structural Engineers” for an international competition held in 2011 by the Vila Franca de Xira Municipality, winning 1<sup>st</sup> prize.

### 2. Concept

The programme was to connect directly the urban centre of Forte da Casa, a residential district in the Vila Franca de Xira County, in the outskirts of the city of Lisbon, with the Tagus Estuary Riverside Park. Forte da Casa is not a very interesting urban area, with a high density traffic road and a busy railway cutting it off from the natural spaces along the bank of the river Tagus estuary, most notably from the Riverside Park. Hence, a single gesture bridge was materialized in a straight line that minimizes complexity and reduces the impact on the horizon of the river Tagus plain.

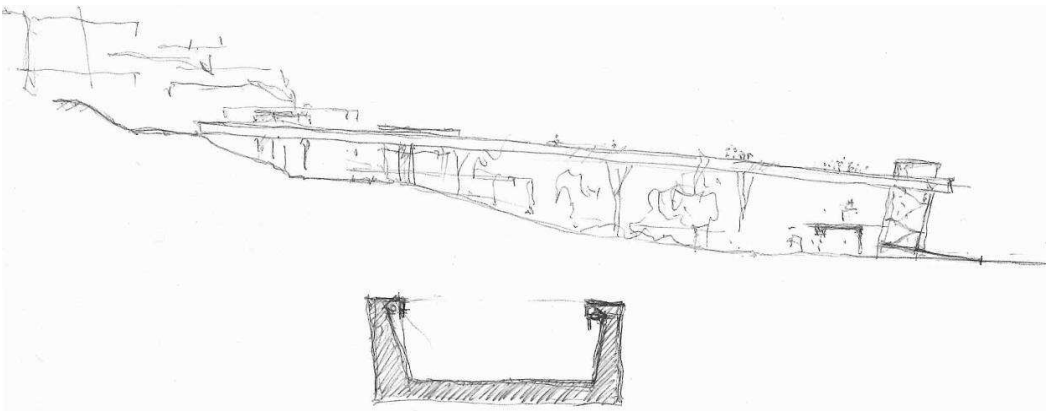


Fig. 1 - Footbridge concept

Indeed, “The new pedestrian bridge is configured in a single object with a strong identity. A simple gesture in a complex urban reality, capable of becoming an iconic structure within the urban space and the Tagus flatlands” (Telmo Cruz - Architect).

The overpass interconnects three main spaces: from an park in the urban centre of Forte da Casa, it crosses the

national road N10 into a corridor of space occupied by residential buildings and a number of commercial malls, and, to the east of the railway track, into the Tagus Estuary Riverside Park, on the right bank of the river.

The bridge has to comply with minimum imposed heights above the railway (complying with the minimum distance to the electrical catenaries) and with a minimum height over the N10 road. Connecting these two points, a line slightly inclined in the direction of the river is obtained, that is transformed into a single linear object interconnecting the three spaces above.

Therefore, the bridge will play a leading role in the movement of individuals in the area: walk, bicycle, skateboard or skates, Segway, etc, essentially non-motorized and not pollutant. In this sense, the bridge becomes a benchmark of mobility and urbanity, where sustainable development is increasingly important. A simple bridge well connected with the surrounding space, simple both in its formal definition and in its constructive definition.

### 3. Bridge Geometry

The bridge will be approximately 220 m long - a straight line on plan and with a constant slope across the valley. It is made up of 7 spans, the biggest of which is 42 m above the railway track connecting Lisbon to Porto, the other important city in the north of the country. On elevation, the desired visual lightness is expressed by the slenderness of the cross section, 1.50 m high and 3.50 m wide, so that, at a distance, it appears as a simple line taking off over the valley.

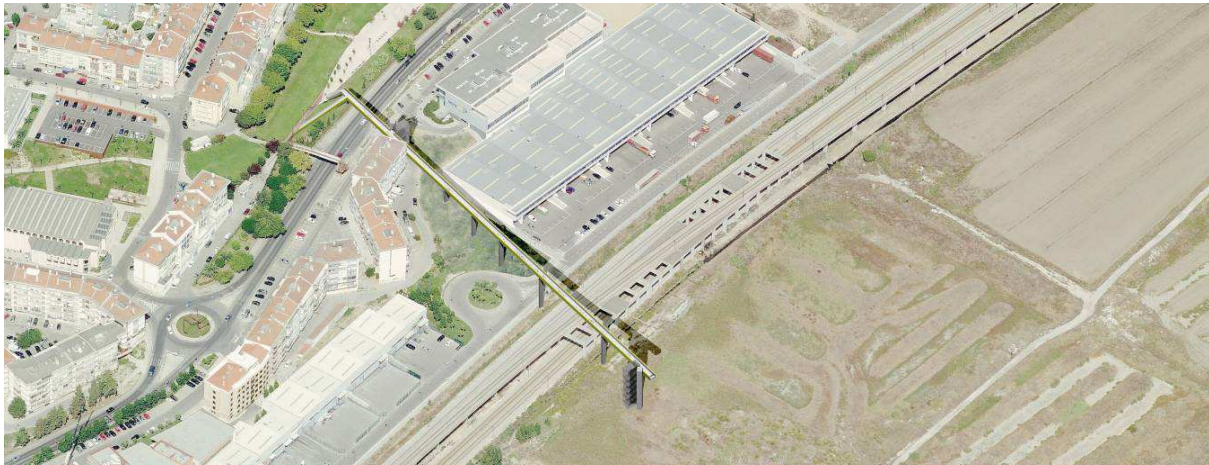


Fig. 2 – Aerial view (photomontage)

The bridge provides access to and from the residential and commercial area at an intermediate support. Due to the shortage of available pedestrian public space in this area, this support is located in an area currently occupied by some parking spaces, where the pavement levels will be redefined in order to create a platform for the safe and comfortable movement of pedestrians and cyclists, while maintaining existing connections to the residential buildings and to the shopping mall.

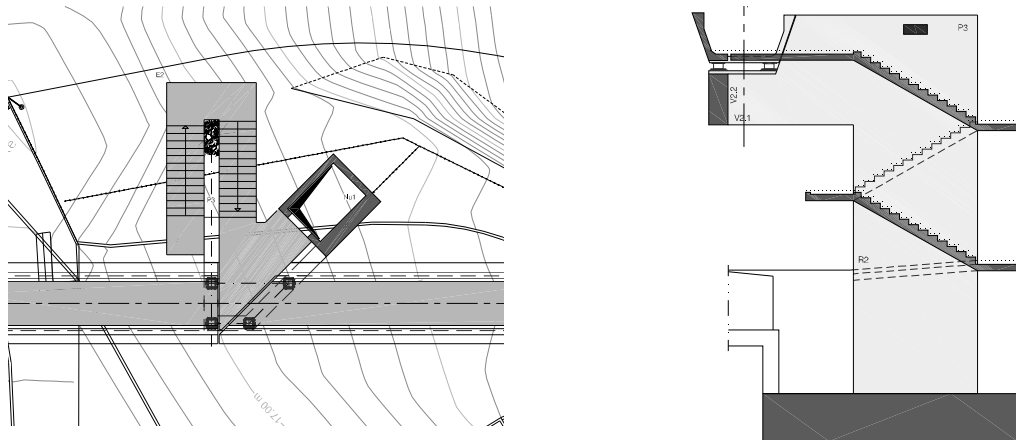


Fig. 3 – Intermediate support (plans and sections)

Access to / from the new footbridge is provided with one lift and stairs, since a connection ramp is not feasible, due to the reduced space available and due to the height from the ground level to the bridge deck. Both stairs and lift are laterally adjacent to the bridge. The deck is supported by a cantilever beam coming out of the column around which the stairs are also supported, and by a cantilever beam coming out of the lift shaft.

Once up on the bridge deck from those stairs or lift, pedestrians and cyclists can cross over the N10 road in the direction of the existing public space, and from there to the urban centre of Forte da Casa through the existing roads and paths. The connection of the bridge deck to the public park (and then into the urban centre of Forte da Casa) is made by using a flight of stairs or a ramp approximately parallel to the N10 road with slopes below 5%, for handicapped people.

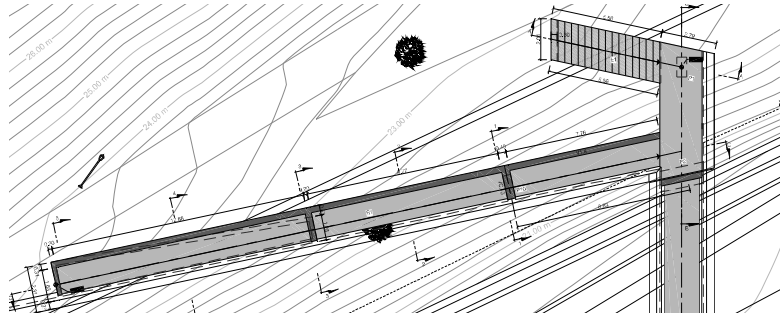


Fig. 4 – North access (plan)

In the other direction (SE), the bridge is very long – almost 180 m – leading to the Tagus Estuary Riverside Park. When at the SE end of the deck, its level is around 20 m above the ground level, so a connection ramp is not feasible because a slope of 5% would mean 400 m of ramps. Again, access to / from the bridge is available by lift or stairs. The deck is also supported on cantilever beams springing from the column and the lift shaft.

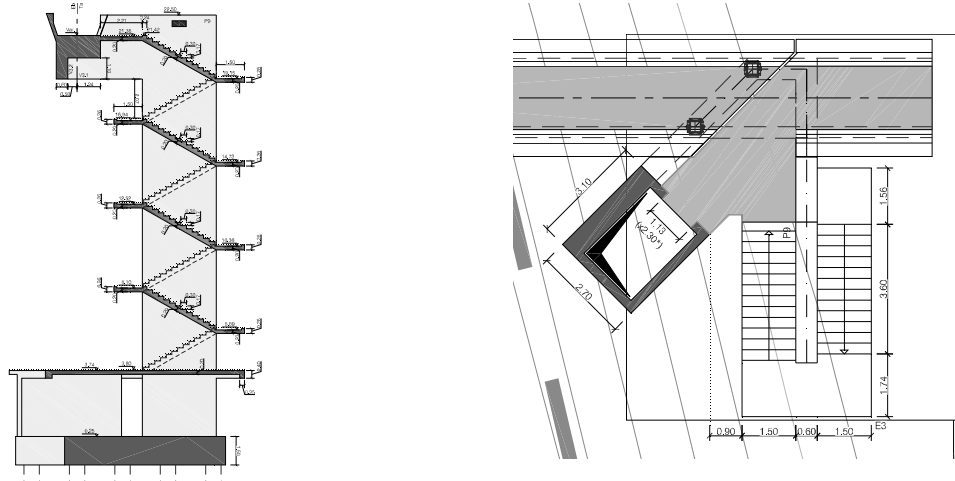


Fig. 5 – SE support (plan and section)

The height of the deck above the ground recommends the use of opaque and high guardrails, in order to mitigate any sense of vertigo and exposure to wind. Therefore, a U-section was chosen for the deck, with external dimensions of 3.25 m (width) by 1.50 m (height), from which 2.50 m is the available width for pedestrians, with the deck 1.10 m below the top of the guardrails. The deck is essentially a precast pre-stressed concrete U section in most spans, becoming a steel section in the span above the railway lines, where the span is larger and where speed of construction is very important. For this span, the use of a pre-fabricated steel deck seems a solution able to provide both structural and erection conditions.



Fig. 6 – Internal view with the Tagus as Landscape

This is a type of bridge with proven effectiveness that integrates beams and guardrails in one element, thus optimizing the use of the structural material. This hybrid beam / guardrail element also includes a set of technical facilities as lights, which will be provided by LED luminaries that optimize maintenance cost.

As described above, the spans of the bridge are heavily conditioned by the railway, the N10 national road and the various local accesses, so the position of the columns has to be such that there is no interference with those accesses. Therefore, the span above the railway will be approximately 46 m and the span above the N10 road will be 35 m, and that is an extremity span. There are more 3 intermediate spans of approximately 27 m and another adjacent to the railway span of about 30 m. As said before, the span over the railway is in steel, becoming a concrete deck again for the last span of 22 m to achieve the south access to the park below. Beyond this point, the deck exhibits a 3.50 m cantilever as a balcony facing the Tagus flatlands.

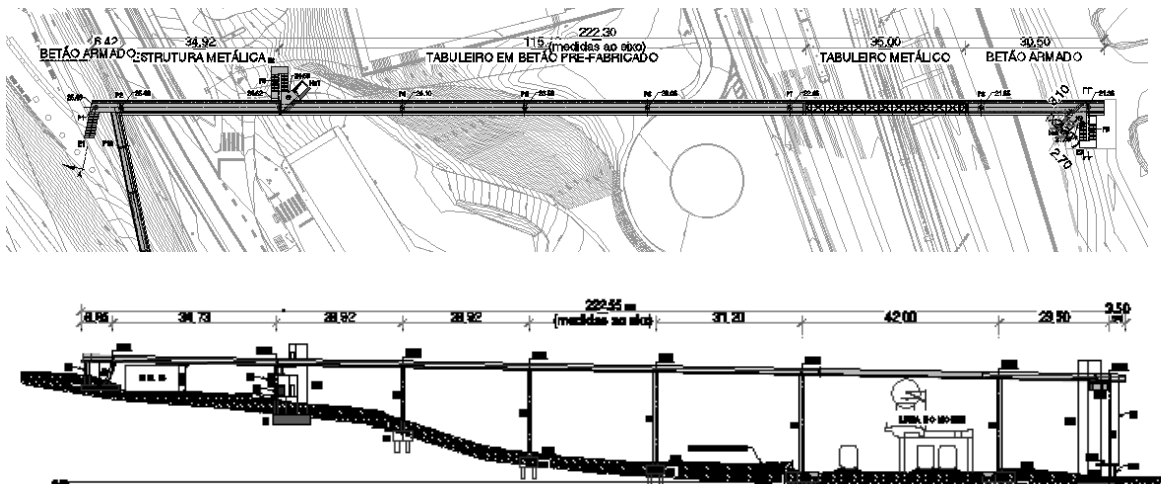


Fig. 7 – Bridge plan and elevation

The structural response of the bridge subject to vertical loads is essentially of two parallel continuous beams, supported on intermediate columns and on abutments. Particularly important are the effects of temperature, wind and earthquake, which determine the support conditions in abutments and columns. Columns are fixed to the pile caps at their base, but links between them and the structure of the bridge's deck takes into account the need to ensure both the locking of the columns in the direction of lower inertia and the minimization of effects of deformations of the deck due to thermal variations.

The steel section is formed by two longitudinal steel girders, which, together with the transverse frame supporting the pavement, form "U" cross sections. These two longitudinal steel beams define a free width of 2.5 m between flanges. The cross section of each girder is composed of two eccentric flanges connected by a solid inclined web and by two



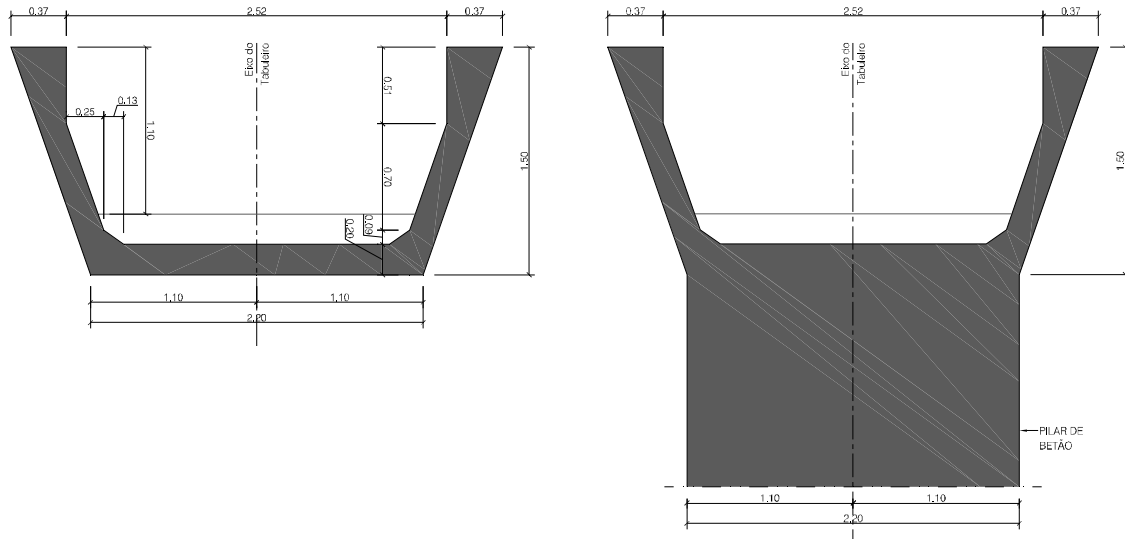


Fig. 10 – Concrete section

Connection between concrete and steel decks is a crucial aspect of the design. They are accomplished through transverse diaphragm zones comprising a mass of reinforced concrete and a steel diaphragm. Convenient design of diaphragms ensures transmission of shear forces, torsion and bending moments. Transmission of shear forces induced by shear and torsional moment is achieved through connector studs welded to the webs of the steel section. Essentially, transmission takes place in a section where negative moments are predominant. The transmission of compression forces is made directly from the concrete lower flange into the steel diaphragm and into the lower flanges of the steel section. Tension forces are absorbed by the upper reinforcement, welded directly to the upper flange of the steel section. Deviation forces caused by the eccentricity between points of application of forces are absorbed by additional reinforcement placed in the form of stirrups. Design safety of steel elements (transverse ribs and diaphragm) was performed using simplified models of balance of forces. Results were confirmed with a local model of shell finite elements.

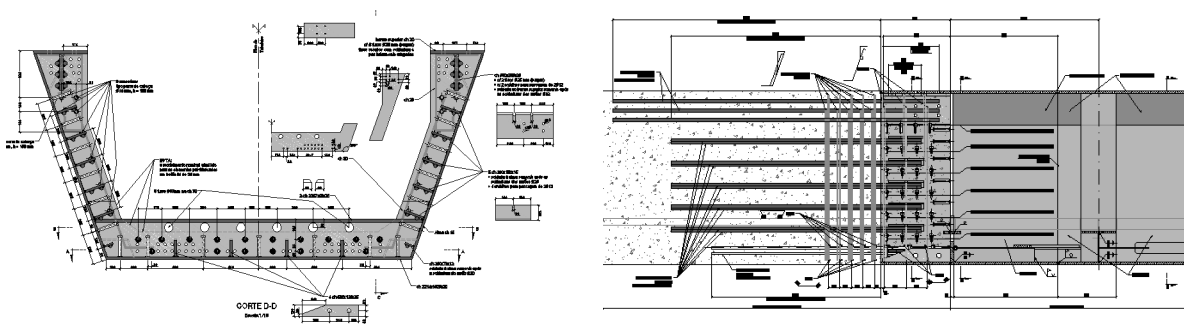


Fig. 11 – Connection between steel and concrete sections

Given the lack of bearing capacity of the upper soil strata in the most part of this area, piles are used to mobilise the miocenic soil formations, characterized by values of NSPT > 60. These formations are deeper at the foundations nearer to the river, so the piles vary in length from 8 m to 18 m. At the NE extremity of the bridge, rock formations were found near the surface, so direct foundations are used where this occurs.

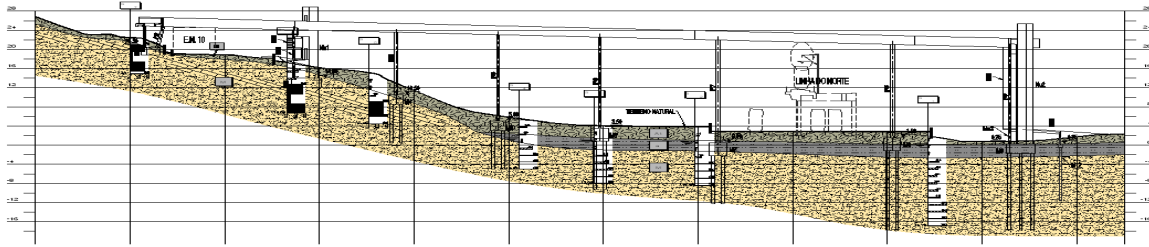


Fig. 12 – Geological section

#### 4. Construction sequence

Construction methods for foundations, piles, columns and lift shafts are traditional. Prefabricated concrete decks will be transported to site and will be lifted into position above the columns using cranes, and insitu concrete will be used to connect the spans between them. Concrete spans adjacent to the steel deck will be prefabricated with steel noses, onto which the steel span will be welded. This process ensures a quick construction time over the railway, which will be closed for some hours during only one night.

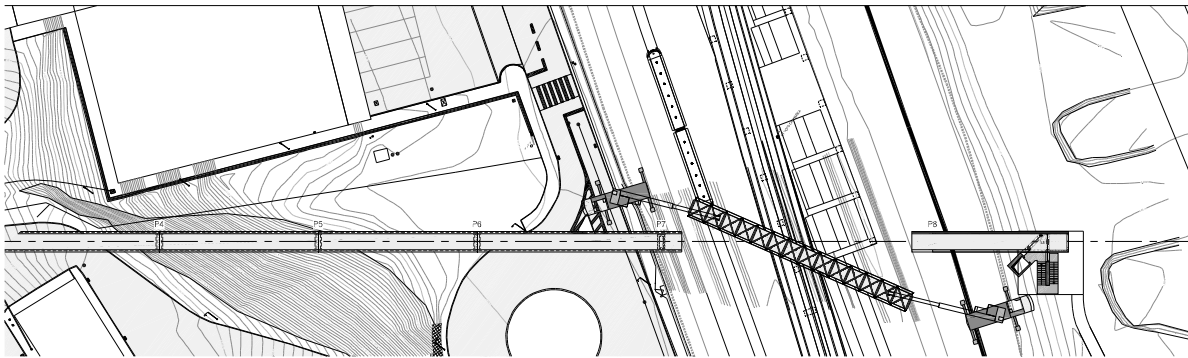
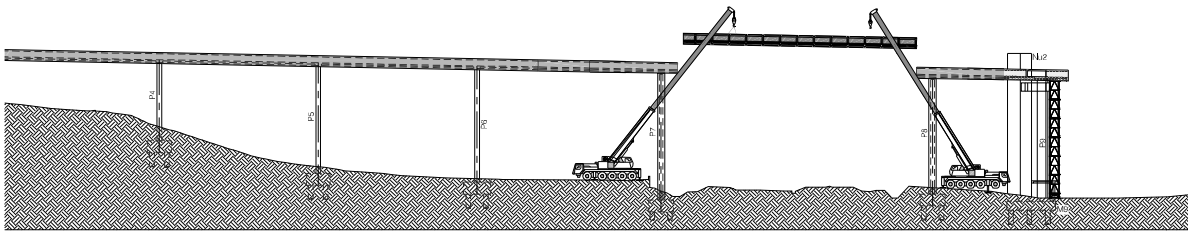


Fig. 13 – Construction Sequence

The bridge is currently under construction and will open to the public in mid-spring 2014.



Fig. 14 – Construction photos

## 5. Acknowledgements

Acknowledgements are due to our colleagues at “Adao da Fonseca – Engenheiros Consultores” for their contributions to discussions in which many of the final solutions were generated.