Design of dedicated lane infrastructure

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1 Executive summary

In the future cities the need for integrated traffic solutions, which provide a more effective organisation of urban transport and require mobility in an efficient, safe and economic way, is becoming bigger every day, as cities throughout the world are moving towards increased concentration into megalopolises.

The global objective of the CityMobil project is to achieve a more effective organisation of urban transport, resulting in a more rational use of motorised traffic with less congestion and pollution, safer driving, a higher quality of living and an enhanced integration with spatial development.

Within the CityMobil project three large-scale demonstrations and several small demonstrations have been planned to apply, validate and demonstrate the concepts and tools developed in the project. These demonstrations will present real implementations of innovative transport concepts. The large demonstrations are located in the airport of Heathrow, at the new exhibition building in Rome and in the city of Castellón.

The objective of the city of Castellón is the implementation of a hybrid transport system connecting the cities of Castellón, the university and city centre and the Benicassim at the seaside. The Castellón demonstration will provide for considerable flexibility in operations. A suitably adapted bus/tramway could travel on a guideway where this is available but could also travel on any other part of the road network as required, something especially useful in the city centre.

The present deliverable is focused on the definition and design of the dedicated lane used for the Castellón demonstrator.

2 Introduction

Thanks to the tourist label "Costa Azahar" the seaside of Castellón is one of the fastest growing areas in the Valencia region - in 2004 the Region of Valencia received more than 20.7 millions of tourists, which means more than four times the population of the region.

In order to keep up with this growth, thousands of new houses – mostly second residences for both locals and European long-term residents- are being built and public transport is a key part of the new infrastructures to be developed. In this context, a new airport is under construction in Castellón and the Regional Government of Valencia has already stressed the strategic importance of the city of Castellón and its metropolitan area.

In order to tackle these challenges a number of interventions are planned, among which the current pilot plays a key role. The first line of the advanced transport system – northern corridor - will provide service to the University Jaime I, the historical centre of the city, the important settlements in the seaside and the beach in Benicássim, an important tourist resort located 20 kilometres north. The layout of this line will connect therefore the main centres of mobility: University, Intermodal Station, historical centre, commercial centres, Port and beaches. In a second phase, a second line – southern corridor, not foreseen within the current scope of CityMobil - will also connect the south of the metropolitan area (Almassora, Vila-real, Burriana).
Figure 1-1: Area map with planned system trajectory

Figure 1-2: Demonstration trajectory
2.1 Situation after the dedicated lane construction

2.1.1 Town-planning Proposal

The town-planning proposal involved in Castellón demonstration pretends to create a high quality and cosmopolitan urban space for the city. Castellón will take the advantage of the possibility to implement the first urban transport system on a dedicated lane to make it become the urban image of the whole city. Therefore, the main goal is to achieve a quality solution to build the new Castellón public transport axis.

2.1.2 Gardening and watering

The gardening and watering proposal can be easily split into three different stretches, which match the three big avenues where the transport system will be implemented.

- Castellón University stretch
- Riu Sec or University Avenue
- Morella’s Garden or Castellón’s Botanic gardens

The watering net has been divided into three stretches depending on the available points to connect to the existing general water network provided by the enterprise charged with the water supply in Castellón.

The first stretch comprises all Morella stroll. This section is equipped with watering systems for the plants pots seated in the South pavements of the stroll, the trees and shrubs seated in the basins the North pavements and the garden next to bridge over the Riu Sec river.

The second stretch, University Avenue, comprises all the way between the bridge and the University. This section is equipped with the watering systems of the trees next to the dedicated lane.

Finally in the last sections of the dedicated lane, located within the campus of the UJI, a watering system for the landscaped zones to be substituted and the new trees and shrubs to be planted next to the layout of the platform has been.

The areas covered with grass will have a drip underground irrigation installation buried at 12cm approximately, with a dripping of 2.3 l/h, every 50cm.

The trees will have an irrigation system which consists of a 2.0m long ring-shaped conduction, buried at 15cm underground approximately made with a low density polyethylene pipe of with 5 integrated droppers of 2.3l/h.

2.1.3 Environmental integration

Although this Project is not submitted to the Environmental Impact Evaluation since it is not compulsory with the current law (rearrangement of the public transport on urban medium), a section of Environmental Analysis is included in the project; this section contains a study of the planed actions, a study of the environment, the detection and evaluation of the effects, analysis and environmental selection of alternatives, and definition of correcting measures. The structure of this section is the following:

- Short description of the actions involved in the Project, from the point of view of its environmental implications.
- Environmental description of the surroundings.
- Environmental actions to be developed in parallel with the constructive ones, to achieve the highest environmental integration.
Being shown the scarce environmental problematic of the Project, the actions finally defined are basically oriented to the landscape gardening and conditioning of the avenues affected by works, including the following performances:

- Environmental monitoring of works: An environmental monitoring of the works is planned all through its development, in order to guarantee the correct execution and effectiveness of the projected environmental integration measures.
- Planting and landscape gardening: It is planned to plant Siberian elm trees, in the parking zones of Morella Avenue and the Riu Sec Street.
- Flowerpots holders with autochthonous plants and flowers will be planted with aromatic species that progressively will open the way to colours species, especially geraniums with four chromatic varieties.
- All the green space of the UJI stretch, affected by works, will be restored to its original conditions, regarding vegetal species and street furniture.
- Watering networks: Several watering networks have been planned in order to guarantee the suitable development and conservation of the projected plantations.

3 Previous studies

Previous to the design of the dedicated lane several studies have been made in order to ensure the correct design of the infrastructure. The most relevant studies are the following.

3.1 Traffic studies

To make any change in the transport system it’s necessary to have an evaluation tool which allows us to assess the effects that will be produced by these changes, especially those that mean changes in the election of the type of transport (public or private) or the itineraries that the users choose for their routes.

The traffic study is based on the transport model made for the demand analysis, and the main effects and actions on the traffic considered are the following:

- Set the Morella Avenue, from its linking with the CV-151 till the Ribalta Park, as an avenue only to entrance the city.
- Set the Cardinal Costa Avenue as a way to exit the city.
- Reconvert the University Avenue in an avenue with a lane for each direction and a reserved platform in centre.
- Redesign of the intersection between the Vall d' Uixò Avenue and Pintor Oliet and with the Morella Avenue.
- Redesign of the roundabout on the city entrance by the CV-151.
- Opening the Barcelona Avenue following Teodoro Llorente Street.
- Establishment of a traffic priority system all through the layout that assures the fluidity of traffic in the platform.

Once the city traffic network has been modelled, it can be seen that this redistribution of the traffic is not going to trouble the fluidity of the traffic in the zone influenced by the new lane.

- The expected traffic flow at the CV-151 entrance is about 9,800 vehicles per day, which is perfectly assumable by a roadway of two lanes with three lanes at the traffic lights waiting points. A generic estimation of rush hour traffic of 11% of the total and "a
typical” capacity in urban traffic (1,500 vehicles per lane and hour of green light), this assures the capacity of the designed roadway.

- The car density of the cemetery side exit (109 street) will surpass the 14,000 vehicles per day. The designed road, with four lanes in the widest point guarantees a proper fluidity of the traffic.

- More than 15,000 vehicles are foreseen to be circulating around the final part of the Morella Avenue, but this won’t cause traffic problems either, as long as a suitable traffic light program is designed to make this flow compatible with the flow foreseen in Teodoro Llorente Street, more than 4,400 vehicles in north to south direction.

The exit traffic on Ribalta Avenue, between the Independencia square and the Barcelona Avenue, will be slightly increased, and when the Clavé square was reopened to the traffic, the vehicle flow to enter the city will be distributed through this later route instead of the former.

3.2 Cartography
In order to develop the constructive project with the greater possible accuracy a topographical survey throughout the layout has been made. In this topographical survey, techniques of space measurement such as GPS in RTK system, and classic measurement techniques urban zones were integrated.

For the complete development of the project, the following works were carried out:

- Allocation of five layout bases, from which initiate the topographical survey, with CPS receivers, in RTK system.
- Allocation of auxiliary layout bases, for classic topography.
- Topographical survey of the of dedicated lane network for the Castellón public transport.
- Processing of the data obtained by fieldwork

3.3 Material options and comparison
Several materials have been considered to build the several infrastructures needed for the dedicated lane.

3.3.1 Foundations Recommendations
It is recommended not to lay the foundations on grounds characterized by bio-disturbance processes or altered by others causes, nor on levels of uncontrolled entropic fillings.

The existing gravel and zoned scabs in the study area show sufficiently apt geo-mechanics properties for supporting the loads transmitted by the foundation of a construction and, in general, by those of a bridge. However, since the exact characteristics of the bridge structure are not known and considering that is normal to choose deep foundations on river beds (to diminish the risks of the river taking off of the laying of foundations), from the geo-technical point of view, both solutions will be considered as viable, giving all the possible information, so that the best option for the foundations is chosen, based on the rest of technical criteria (term conditions of term, execution conditions, requirements,…).

For a superficial foundation we consider the fundamental requirement that the foundations will lay on a non-altered by the vegetation or other causes ground. Given the alternation of granular gravel levels, of sands levels and/or slimes and conglomeratic scab, determination of the permissible tension must be carried out considering the most restrictive conditioners, this way introducing a suitable criterion to diminish the risk of a breakage by punching.
Therefore, it is considered that the laying of foundations will fall on natural land, of granular and scabbed character.

With these conditions, after tensions and seating being calculated, a conclusion has been reached; when applying a tension of up to 3.50 kp/cm², the estimated seats are lower to the seats specified by norm NBE-AE-88 for a wide range of foundations sizes. Considering the geologic context in which the works are located, it is considered that this tension value can be used for both banks of the river.

Regarding the consideration of a deep laying of foundations, considering that often all the techniques are valid and the election among them is either an economic, of terms or execution problem, the previous specifications lead to consider as suitable solutions, according to NTE A+C norm, either a foundation by extraction piles with recoverable embedding or by means of piles with shirt loss and, mainly, due to the determining factors of the execution imposed by the hard conglomerated scab layers, and the possibility of intercepting skittles during the drilling, the most viable option may be micro-piloting.

The use of displacement piles or sunk vertically in the land is ruled out, since the consistency and general compactness of the land can cause that the sunk length of the pile to be insufficient, in addition to the problems that the breakage of the piles will cause.

According to the test results it can be said that the ground under study IS NOT AGGRESSIVE for the concrete, according to EHE norm.

On the other hand, the Earthquake-resistant Construction Norm: General part and Building (NCSE-02) fulfilment is not compulsory, although the application of the indicated rules of design, especially those regarding foundations, is highly recommended.

Considering the study data, the drilling affecting the most superficial land levels (until the 3 or 4 meters depth), will be able to be carried out by conventional mechanics means. However, if excavations on deeper levels are required, these will have to be made with a hydraulic hammer, especially in the well-cemented stretches.

If during the excavation variations in the lithology occurred, the design and calculation of the foundations, as well as the definition of definitive the structural characteristics, would have to have to be adapted to the new conditions.

### 3.3.2 Platform Recommendations

From the data of the Load with Plate tests made, we can see that in the three points taken its types of esplanade could be already characterized, being, E1 type in Morella Avenue (test pit 1), and E2 type in the points of the Borriol highway (test pit 2) and next to the UJI (test pit 4).

If we only take into account the ground classification obtained from the tests made on the sampled materials forming the esplanade nowadays, this is made of Tolerable ground in the stretch of the Morella Stroll (test pit 1), going through the highway towards Borriol (test pit 2) until the point of study next to the Riu Sec (test pit 3), and of Adapted ground in the zone next to the UJI (test pit 4); so in both cases it would have to be adapted to form the type of esplanade required.

**Esplanade construction.**

For the construction of the esplanade from a tolerable ground, according to the Highways Instruction - 6.1-1C Norm – Road surface sections (Order November 2003), it will be needed to contribute with borrow pit material of 75 centimetres thick of classified as selected material to make an esplanade of type E2, or 60 centimetres of adapted material to form an esplanade of type E1. For both types of esplanades, once the material is extended and compacted by layers, the value of $Ev_2$ will be verified by doing a load with plate test “in situ”, according to NLT 357/98.
For the construction of the esplanade from an adapted ground, according to the instruction mentioned above, it will be needed to contribute with borrow pit material of 55 centimetres thick classified as selected material to form a esplanade of type E2, or to have at least 1 meter layer of adapted material to form a esplanade of type E1. For both types of esplanades, once the material is extended and compacted by layers, the value of Ev2 will be verified by doing a load with plate test “in situ”, according to NLT 357/98.

The exposed on the previous paragraphs is just a recommendation, as there are more models for the creation of these esplanades.

4 Route design and characteristics

The route of the lane begins at the University area, continues through the University Avenue until crossing the Riu Sec River through a new designed bridge. After that it goes into the roundabout proposed for the crossing of the Castelló entrance from the CV-10, it runs by the Morella Stroll and crossing the Vall D’uxo Avenue to finish its way near the Ribalta park.

The section of the dedicated lane is 7 Metres width.

The surrounding constructions are industrial buildings at the beginning of Morella Stroll, and urban buildings until the end of the stroll.

The route milestones and the most important equipment in the surrounding area are:

- The transports interchange station.
- The Ribalta park
- The University Jaime I.

The main materials used all through the route are the different kinds of pavements, with several materials and colours, cobble and paving stones, several types of kerbs, in the lane and the platforms and street furniture with different types of flowerpots holders, banks, litter bins, etc.

4.1 Introduction

This section tries to give a complete definition of the geometric characteristics of each one of the axes projected on the demonstration that constitute the network of dedicated platforms reserved to the public transport in Castellón.

Two sets of axes must be clearly differentiated. The first set corresponds to the dedicated lane axes, and, the other one corresponds to the axes of the avenues of new plan, that were necessary to integrate the existing road network with the new land use transportation planning.

The layout of the dedicated lane sets off the square next to the University Jaime I, and runs throughout the Jaime I Avenue, towards the Riu Sec River, crossing it through a cable-stayed bridge. This bridge connects the Jaime I Avenue with the Morella Stroll, becoming a new road axis that connects centre of Castellón directly with the new city zone near the UJI, simultaneously that facilitates the access to it.

The intersection of the Jaime I Avenue prolongation with Morella Stroll is solved by means of the definition of a series of traffic islands that facilitate the vehicle circulation, giving priority to the high tech buses over the other vehicles at the same time. The dedicated lane extends throughout all the Morella Stroll until Ribalta Park.
4.2 High Tech Buses requirements

The design of the infrastructure project for Castellón demonstrator required the consideration of special characteristics directly arising from the use of High Tech Buses.

The layout of the dedicated lane is directly influenced by the vehicles physical and operating specifications (width, nominal speed, steering diameter at automated mode, requirements for automated-manual mode change...).

An electrical overhead system is also included in the design. Advanced buses have capabilities to operate both with fuel and electric energy. Therefore, this system will permit the buses not only to operate with electric engines on its dedicated lane, but it will also charge the batteries to reduce the fuel consumption and emissions during the part of the trip on shared lanes.

Dedicated lane ground is equipped with the horizontal signs required by the optical guidance system to follow the lane on automated mode and dock the bus stops.

At last, design of bus stops is also affected by the HTB requirements. Height and slope of these stops must fulfill some requirements to achieve a correct automatic docking of the bus, leaving the specified distance between the stop and the bus floor. Its design is also influenced by vehicles size and automated-driving mode, since up to two buses must be able to automatically dock at certain stops.

4.3 Dedicated lane design

4.3.1 Initial data

To develop the dedicated lane layout several documents were consulted. These documents are the following:

- Recommendations for project and design of urban roadways. Ministerio de Fomento.
- Technical Documentation corresponding to the different commercial vehicles analyzed.

The layout criteria used for the definition of the avenues are gathered in the first two publications mentioned above.

4.3.2 Route definition

4.3.2.1 Dedicated lane layout

The dedicated lane layout has been projected independently, defining an axis for each way, since both axes are not parallel throughout the route.

Axis 1 has its beginning PK in the UJI, whereas its final PK is located next to the Ribalta Park. It is 2,040.548 metres long.

Axis 2 has its beginning in the Ribalta Park and runs sensibly parallel to axis 1, until the stop located in the UJI, where its final PK is located. It has an overall length of 2,037.351 metres.

Three complementary axes have been defined, axis 3, axis 4 and axis 5, these axes are located at the UJI stop, and allow the access to the new platform defined on it, as well as the existing stop. Their lengths are much shorter than the previous axes, being of 85.141, 96.19 and 87.496 metres, respectively.

Each axis has been obtained by means of an iterative process in which the projected plan has been simulated considering the sweeping effect of the back wheels of the vehicle. The value of this sweeping has been studied for each case, since it depends on the radius and the length of the curve arc.
In order to calculate the exact curve packing, a simulation throughout all the layout of each axis was made, in which it was considered, in addition to the sweeping effect, different factors such as the vehicle manufacture tolerances, the wind, the safety margin... These simulations have been made with a specific simulation program throughout the entire layout in the singular points, in order to verify the exact sizing of the platform.

4.3.2.2 Roads and routes

The dedicated lane definition in built-up surroundings, as in this case, affects various avenues surroundings. A total of 9 complementary axes corresponding to avenues that have been modified slightly or been newly planned, have been defined. These avenues solve the traffic problems generated by the construction of the new platform.

4.3.3 Vehicles geometric characteristics

The geometric characteristics of the vehicles that are foreseen to use the dedicated lane and for which the simulations have done are shown in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Empty (mm)</th>
<th>With freight (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of the axis</td>
<td>1196 +10/-15</td>
<td>1210 +10/-15</td>
</tr>
<tr>
<td>of the vehicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to the front</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wheels axis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of the axis</td>
<td>1225 +10/-15</td>
<td>1233 +10/-15</td>
</tr>
<tr>
<td>of the vehicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to the central</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wheels axis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length of the axis</td>
<td>1225 +10/-15</td>
<td>1233 +10/-15</td>
</tr>
<tr>
<td>of the vehicle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>to the back</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wheels axis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width from the</td>
<td>1263 ±5</td>
<td></td>
</tr>
<tr>
<td>vehicle axis to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the curb in the</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor base</td>
<td>5355</td>
<td></td>
</tr>
<tr>
<td>Truck base</td>
<td>6765</td>
<td></td>
</tr>
<tr>
<td>Access height to</td>
<td>320 ±25/-45</td>
<td></td>
</tr>
<tr>
<td>the doors.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.3.4 Layout geometric tolerances

- At the stops, the road cross-sectional slope will be limited to 2%, since with a bigger inclination the minimum approach distance for the vehicle to the platform is not guaranteed.
- At the curved sections the maximum bank will be fixed to 5%.
- The Maximum variation of the longitudinal pitch will be fixed to 2% each 10 meters and a 2% per second (this parameter will be verified based on the maximum velocity allowed for the vehicle for each section).
- The longitudinal slope will not be higher than 13%.
- The minimum curvature radius will be 300 meters.
- The layout will be constituted only by straight sections and clotoids (curves with special characteristics that provide adaptation between straight and constant radio curved sections), and constant radius curves.

In the case that the road cross-sectional slope towards the stop is 2%, it will be necessary to consider the vehicle drift effect during the stop approach as well as during the setting off
again. For that reason, it is advisable that the approach and separating to/from the stop is progressive to make the approach/separation to/from the platform easier.

4.3.5 Ground plant layout
The ground plant layout can be obtained from the following general considerations:

- Provide the layout with a geometry according to Instruction 3.1. - I.C.
- Respect and maintain existing road network, adapting the new avenues to the existing ones, maintaining their continuity, and solving the possible traffic conflicts caused by the implantation of the new platform.
- Getting the maximum coordination possible with the ground plant layout.

4.3.6 Elevation layout
The elevation layout can be obtained from the following general considerations:

- Provide the layout with a geometry according to Instruction 3.1. - I.C.
- Respect and maintain existing road network, adapting the platform slope to the existing ones.
- Getting the maximum coordination possible with the ground layout.

4.3.6.1 Minimum transition curve parameters
The current standard establishes the minimum curve parameter values to ensure visibility, making distinction if the curve is convex or concave. In the table below, the minimum values to fulfil the geometric conditions indicated by the vehicles studied makers are shown. The desirable minimum value is that corresponding to the designed speed increased in 20 km/h

<table>
<thead>
<tr>
<th>VEHICLE Length = 12 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concave radius in freight</td>
</tr>
<tr>
<td>Radius = 38,603 m</td>
</tr>
<tr>
<td>Convex radius in freight</td>
</tr>
<tr>
<td>Radius = 22,983 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VEHICLE Length = 18 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concave radius in freight</td>
</tr>
<tr>
<td>Radius = 48,408 m</td>
</tr>
<tr>
<td>Convex radius in freight</td>
</tr>
<tr>
<td>Radius = 49,009 m</td>
</tr>
</tbody>
</table>

Additionally, it must be verified that the length of the parabola in meters is bigger or equal than designed speed in km/h.

In the projected elevation cash the minimum values for the parameters in concave and convex agreements, as well as the lengths in agreement have been observed.

4.3.7 Structure gauge analysis
The basic criteria considered for the sizing and design of the dedicated lane, have been determined from a height analysis.
To make this analysis, several commercial vehicles and their design characteristics have been taken into account trying to unify criteria, in order to design a dedicated lane which allows the use of a wide range of vehicles (buses, guided buses, etc) so that these can circulate without width, radius of curvatures or height problems.

Therefore, throughout the platform layout the following elements have been studied with detail:

- The platform layout and structure.
- The stops
- Packing and height limit throughout the whole layout.
- Bridge height.
- Optical guidance system.
- Garages necessary Infrastructures.

4.3.8 Packing values

For calculating the security global packing, also known as width limit, the following parameters have been taken into account:

- The characteristics of the vehicle: dynamic height, manufacture tolerances, etc
- The wind influence.
- The accuracy and/or failures of the vehicle optical guidance system.
- The failures of the vehicle (such as a puncture or a flat tyre, suspension problems, etc)

In order to calculate the exact packing in the curves, it will be necessary to make a simulation of the entire layout, in this simulation several factors, such as the sweeping effect, the vehicle manufacture tolerances, the wind, the defined safety margin, etc., will be taken into account.

4.3.9 Bridge gauge

In order to establish the basic criteria of design of the vertical patterns Norm 3,1 1-IC of Layout of the Instruction of highways has been taken as a reference, where in section 7.3.7 the minimum vertical clearance under upper crossings on any point of the platform will not be inferior to 5.30m in interurban highways, and the minimum vertical clearance under footbridges or porches, on any point of the platform he will not be inferior to 5.50m.

Therefore, considering this norm, and considering the most unfavourable situation the limit of the vertical pattern has been settled down at 5.50m for the design of the bridge.

4.4 Overhead system

When the advanced buses circulate through the dedicated lane they are connected to the electric lane by means of an overhead system which, as well as giving the vehicle the electric power necessary to move through the lane, is used to recharge the batteries needed to allow the bus to circulate outside the dedicated lane.
4.4.1 Structure

The present structures in this phase are those necessary to build the overhead system: supports, corbels, braces, cross-sectional, plates of anchorage and foundations.

The overhead system used for this transport system is different from the one used for the tramways, as the elements used for the contact wires power point are different for both systems. The overhead system to use is flexible being its main advantages the possibility to reach greater span lengths (up to 35 m) without having to use compensation systems, as well as the important reduction of the cases of contact lost between the power points of the vehicle and the contact wires.

The materials used for the different structural elements are the following:

- Supports: steel cuts.
- Corbel braces: synthetic thread, parafil (synthetic ropes) or equivalent.
- Tubular Braces: steel galvanized in hot.
- Cross-sectional suspension Threads: steel cables.
- Corrugated bars: steel B-500S.

The supports and foundations have been classified in different types depending on the required efforts. To be precise, there are 4 types of supports, from the 1 to 4, and 5 types of foundations, from A to D.

4.4.2 Electrification

The overhead system will ensure the vehicle power supply. The catenary will be flexible with pendulum suspensions, since with this option the supports can be installed with a bigger distance between them.

The thermal expansion does not influence excessively in the Maxima arrow of each section between supports, thanks to the behaviour of this type of catenary before the temperature changes.

The vehicle is supplied with a nominal tension of 750 V in DC. The overhead system consists of two contact wires: one for the positive pole and another one for the current return.

Two poles with a power point in each one of them will be installed in the vehicle. The power point device contains a graphite electrode that, when rubbed with the contact wire, made of copper, assures the power supply of the guided bus.

The contact wire is divided in different sections in order to isolate a possible failure allowing the rest of the infrastructure to continue working. The different catenary sections are supplied by means of feeder cables coming from a traction substation. A set of motorized disconnecting switches will be settled at the substation end, in order to make different provision configurations to increase the reliability of the system.

In the substation design different redundancies have been included so that the security of the provision is guaranteed.
The traction substation has not only transformer-rectifier generating sets for feeding of the vehicle, but also a transformer for auxiliary services. This transformer assures the provision for the different substation equipment and besides provides energy to the stops.

The installation will be made allowing the option of controlling the whole infrastructure from a future centralized control post.

### 4.4.3 Lighting

Throughout all the layout of the dedicated lane a lighting installation has been projected to assure the conditions demanded by the norm in the public roads.

To illuminate the layout of the reserved lane as well as the adjacent routes, the 12 meters high supports, used for the catenary supporting, will be used.

Adjustable projectors with extensive asymmetric equipment, that illuminate the whole dedicated lane and the surrounding roads, will be settled in the upper section of these supports. The distribution of these projectors complements the lighting system existing in the sidewalks obtaining levels of illumination superior to the ones demanded in the decree of the city of Castellón.

The use of this kind of projectors allows obtaining a high longitudinal uniform illumination at the different sections of the avenues.

The illumination of the Morella Stroll zone is complemented with 9 meters high lighting columns, which reinforce the illumination of the zones reserved to pedestrians until reaching the values demanded by the city ordinance.

Two types of lighting system with two different objectives are planned to be installed in the cable-stayed bridge over the Riu Sec River.

Firstly, it is necessary to ensure a safe vehicle circulation through the bridge, not only by the dedicated lane but also by the general routes for vehicles and pedestrians. This objective is achieved by means of installing projectors embedded in the central reserve that delimit the different roads, focused towards the way surface. The pedestrian tracks are planned to be illuminated by means of the installation of fluorescent elements disguised in the structure of the bridge banister, this allows the users to cross the bridge with the enough safety without environmental luminance contamination.

Secondly a spectacular lighting installation that makes the bridge become a reference point in the city of Castellón is planned to be installed. This objective is achieved by illuminating the different elements that conform the bridge.

In the lower part of the bridge a set of projectors with a changing colour system is going to be installed. This coloured system will give the bridge a unique character and will emphasize the structural design.

In the upper part, the central pillar, which reaches the 41 meters of height, is enhanced by means of long reach projectors and the harp-shaped stay ropes will be illuminated by means of projectors with a very small beam-opening angle, which emphasize the length of the ropes.

### 4.5 Traffic signals

The construction of a dedicated lane for public transport in the city of Castellón implies a readjustment of the traffic signals at the crossings points with the dedicated lane, achieving the Maximum security in the city circulation and making the turns and crossings possible for all the vehicles.

The circulation of the high tech buses has been given priority by means of the installation of traffic lights at the crossings and the information to vehicles and pedestrians has been
reinforced with horizontal and vertical signalling. This way it is possible to make the coexistence of the road traffic, the high tech buses and the pedestrians compatible in the city centre.

Traffic lights will be installed at all the crossings affected by the dedicated lane, they will be controlled from the Castellón Traffic Control centre. Additionally, the system will be equipped with a traffic lights priority system for the high tech buses by means of a set of detectors and its connection and coordination with the traffic regulators that will also be installed.

The high tech buses optical guidance special system needs horizontal signs with particular geometric and reflectance characteristics that must be strictly fulfilled.

4.6 Stops specifications

Two types of platforms have been designed for the stops in the dedicated lane, according to two possible situations that will be possible:

- Platform type 1: central deck with lateral platforms, with roads along both sides of it. There are two stops with this configuration: The “Sos Baynat” and “Riu Sec” stops.

- Platform type 2: lateral deck with lateral platforms, traffic road along the North side of the platform and pavement along the South side. The stops with this denominated distribution are the “Paseo de Morella/Intermodal” and “Parc Ribalta” stops.

The platform type 1 has a generic width of 3.00m and is 25.00m long that would allow the simultaneous lodging of two High tech buses units of 12.00m or one of 18.00m. It also has two 2.00 m long access ramps in each side of the stop, to overcome the maximum slope of 6.00%. The height of the platform over the dedicated lane is +0.24m, which enables the easy boarding of any kind of vehicle. The cross-sectional slope of each platform is a 2.00% slope, which implies that the height of the platform over the lateral road is +0,11m. On both sides of the ramps that give access to the platform there is 2.00m long horizontal area protected from the dedicated lane layout by means of a continuation of the frontal profiles of the stop.

The platform structure is built on 98% wet-mixed macadam layer of 0.35m thick. This layer is also a structural part of the dedicated lane. Over the wet-mixed macadam layer a 0.27m thick concrete HM-20 layer will be placed, and over this one another one of 0.03m made out of sand will serve as base for the upper pavement.

The platform surface, as well as the access ramps and adjacent pavements surfaces will be paved with 6,5 x 6,5 x 5cm clinker ceramic pieces. The junction between the roads and the dedicated lane is done with a 20 x 100 x 28cm-prefabricated curb. On the opposite side, the front part of the platform will has a 30/42 x 100 x 39cm, “Kassel” type grading curb. The grading curbs will be placed all along the length of the platform, including the slopes, and they extend, additionally, 2.00m in each direction to protect the pedestrians from the other vehicles circulating around the platform.

The “Kassel” type grading curbs are placed on a concrete HM-20 trapeze.

The platform type 2 has a generic width of 3.50m and one is 25.00m long, that would also allow to the simultaneous lodging of two High tech buses units of 12.00m or one of 18.00m. It also has two 2.00 m long access ramps in each side of the stop, at the north side of the platform, with a maximum slope of 6.00%. The platform of the South side of the deck has a trapezoidal slope that solves the difference in height existing between the pavement, the platform and the deck. The height the platform over the dedicated lane is +0.24m, which enables the easy boarding of any kind of vehicle. The cross-sectional slope of each platform is a 2.00% slope, while the junction between pavement and platform in the South side is made at the same level. If there is a slight unevenness between the platform and the
pavement, the pavement gradient will have to be corrected so that the junction is made at level. On both sides of the ramps that give access to the platform there is 2.00m long horizontal area protected from the dedicated lane layout by means of a continuation of the frontal profiles of the stop.

The platform structure is built on 98% wet-mixed macadam layer of 0.35m thick. This layer is also a structural part of the dedicated lane, just as in the previous case. Over the wet-mixed macadam layer a 0.27m thick concrete HM-20 layer will be placed, and over this one another one of 0.03m made out of sand will serve as base for the upper pavement.

The platform surface, as well as the access ramps and adjacent pavements surfaces will be paved with 6.5 x 6.5 x 5cm clinker ceramic pieces. The junction between the roads and the dedicated lane is done with a 20 x 100 x 28cm-prefabricated curb. On the opposite side, the front part of the platform will have a 30/42 x 100 x 39cm, “Kassel” type grading curb. The grading curbs will be placed all along the length of the platform, including the slopes, and they extend, additionally, 2.00m in each direction to protect the pedestrians from the other vehicles circulating around the platform.

Both kinds of platform are equipped with a 2mm thick stainless steel embossed veneer longitudinal stripe made out of 2.00 x 0.40m pieces, this longitudinal stripe is located 0.60m from the frontal edge of the stop. The object of this longitudinal tape is to indicate a safe distance in a way that it can be noticed blind people.

A 40 x 40cm shaft will be settled in each platform, these shafts will enable the access to the electrical provision and communications facilities. The connections will be prepared for the installation of spending or ticketing machines, illumination and passenger information systems.

In order to protect the passengers waiting for the buses in the platforms close to the roads, a banister will be installed on the platform zones near the traffic roads. This banister will be 1.00m high and will be placed so that its outer edge is positioned at 0.10m over the outer curb of the platform. So, in type 1 stops, there will be a banister in each platform, whereas in type 2 stops, there will only be a banister in the platform near the roadway (the North side platform).

4.6.1 Pavements
The platforms paving will contain the following elements:
- “Kassel” type grading curb: dimensions 30/42 x 100 x 39cm.
- Prefabricated concrete curb: dimensions 20 x 100 x 28cm.
- Clinker ceramics pieces: dimensions 6.5 x 6.5 x 5cm, with five colours chromatic gradation from beige shades to orange/brown.

4.6.2 Street furniture
Each stop will be provided with four (4) litterbins per platform. The typology of these wastebaskets will have to agree with the rest of wastebaskets to be installed all through the dedicated lane layout.

A shelter will also be installed in each stop on both sides of the deck, on each platform.

4.7 Bridge specifications
The crossing over the “Riu Sec” riverbed is solved by means of a cable-stayed bridge with two lights spans of 90 and 15 meters, respectively.
The brace support system has only one pile that starts in a pier from under the deck of the bridge, going through it by a hole specially made for that, and it rises until nearly 41m high.

The bridge tie rods are arranged in harp shape and go from different points of the main span till the higher part of pile; the secondary span is not supported by any tie.

Counteracting cables set off from pile, in a way that they balance their action on the pile. These new ties anchor in a counterbalance arranged after the second span.

There are two brace support system planes; they are located on both sides of the central platform, which is 7m wide. This central section of the platform is separated from the rest of the deck by the ties anchorage heads.

The pile shows a “Y” form, the anchorages of the braces are located in the arms of this “Y”. These arms are orthogonal to the bridge axis, so, the cable stay seams to the orthogonal although the bridge is skew.

The resistant section of the bridge deck is sprayed with prestressed concrete and it is made with two main beams with “p” shape section between whose souls, under the compression slab the anchorage of the braces are located. Following of the direction of the skew there are cross-sectional crossbeams with variable edge, these crossbeams are made of prestressed concrete, these allow transferring the platform load to the main beams. On top of this grid there is a compression slab of 25cm of thickness.

The bridge pile has been designed with a steel hexagonal box girder cross section that slits in two equal parts when the arms of the “Y” separate.

The lower part of the “Y”, until the level in which the arms separate is filled up with concrete. Both arms, nevertheless, are hollow to allow the access to the maintenance of the pile anchorages.

Abutment 1 is a closed type abutment with side wings and it is gunited with reinforced concrete.

The counterbalance acts as abutment 2 and as “ballast” to balance the supporting system. It has a trapezoidal plan, and is made of a set of prismatic cells that support each other and are filled with earth to obtain the necessary weight for the balance. The sidewalls of these cells as well as the soleplate their covers are gunited with reinforced concrete.

### 4.7.1 Frame description

The projected structure is a cable-stayed bridge with two spans with lights of 90 and 15 meters respectively; it has a deep skew ground view, which is next to 55º.

The bridge is straight-lined in the ground view and has slope of 1.10% in the side view and allows the crossing of the dedicated lane over the Riu Sec River.

The system has only one pile, which starts in a pier from under the deck of the bridge, going through it by a hole specially made for that, and it rises up to nearly 41m high.

The bridge cables are arranged in “harp-shape” and start from different points of the main span to the higher part of pier.

The second span is not supported by any cable. Several counteract cables are tied to the pier to balance it. These new cables are anchored to a counterbalance that located after the second span.

There are two brace support system planes; they are located on both sides of the central platform, which is 7m wide. This central section of the platform is separated from the rest of the deck by the ties anchorage heads.
The deck of the bridge platform is 26.30m wide. In the section this width is distributed in a 7m wide central platform for the dedicated lane, two 3.40m wide roads separated from the dedicated lane by a central reserve of 2.25m and two pavements 4.0m each, on both sides of the deck.

In the area next to the pier, the platform of the dedicated lane becomes bigger to allow the vehicles to pass around the pier, reducing the zone of separation between the tracks and maintaining them, as well as the pavements, constants.

The deck resistant section is projected with prestressed concrete and it is built up by two “π” section beams, the tension rods anchorage cubes are located between the beams webs, and under the compression slab.

Following of the direction of the skew, several cross-sectional crossbeams with variable edge and 0.40m of thickness, built with prestressed concrete are located, these beams allow to transfer the platform loads to the main beams.

Over this grid there is a 0.25m thick compression slab.

This section has a minimum edge of 2.05m, although it grows with a convexity of 2% from the centre of the section towards the ends.

The bridge pile has been designed with a steel hexagonal box girder cross section made out of 30mm thick plates that slit in two equal parts when the arms of the “Y” separate. These arms take up the upper 13.3m of the pier.

Several stiffening levels, at maximum distances of 1.25m, are located all through the straight section; these stiffening levels consist of a frame of UPN 300 profiles and two HEB 300 profiles that cross the section centre. There are stiffening 5 levels every 2.40m in each arm. All through the height of the pier there is a longitudinal stiffening consisting of ½ IPE 300.

Abutment 1 is a closed type abutment made of reinforced concrete of 1.35m wall thickness with 0.50m thick side wings. This abutment is lays directly on the ground by means footings of the same material.

The counterbalance is an element made out of reinforced concrete that acts as abutment 2 and as “ballast” to balance the supporting system.

It has a trapezoidal plan, and consists of a set of 2.70 x 4.85 x 5.00m prismatic cells. These cells are filled up with earth to reach the necessary weight to act as balance. These cells longitudinal walls are 0.60m thick and the transverse walls are 0.30m thick, the same as the upper slab. The thickness of the base is 0.40m.

One of the cells contains the set of the counteract anchorage cubes. This cell does is not filled up completely and there is a man crossover on it to give access to the tensing and maintenance of the cables.

The pier is built with prestressed concrete. This pier is 20.8 m long and has a variable thickness between 2 and 5 meters, which allows the lodging of the pillar anchorage inside it.

The foundation of this pier is made with 18 reinforced concrete piles, of 1.80m diameter, joined by a 26.10 x 12.60 x 2.80m layer of prestressed concrete. These piles separated 4.50m.

5 USED REGULATION

The following norms and recommendations are used for the elaboration of the project the.
5.1 Action norms
(1) Ministry of Public Works. “Instruction on the actions to be considered in the highway bridges projects” (IAP).

5.2 Construction norms
Ministry of Public Works. “Estructural Concrete Instruction (EHE)”.
Ministry of Public Works. “Steel Structures in buildings (EA-95)”.
Ministry of Public Works. “Recommendations for the project of mixed bridges for highways (RPX-95)”.
(6) Ministry of Public Works. “Technical Note on instruments for support the highway bridges”.
(7) Ministry of Public Works. “General Technical Prescriptions Sheet for road and bridges works (PG3)”.
(8) Ministry of Public Works. “Recommendations for the project and execution of load tests in highway bridges”.

6 USED SOFTWARE
The following software programs have been used for the calculation and sizing of the structures of the project:
- ANSYS-CIVILFEM. Program for finite element analysis that determine the displacements, efforts and tensions of a structure, resulting of the imposed boundary conditions.
- FAGUS (Cubus) for the sections calculation, not only for obtaining tensions and deformations but also for verifying the Final State Limit.
- SAP: Program for finite element analysis that determine the displacements, efforts and tensions of a structure, resulting of the imposed boundary conditions.
- PRONTUARIO INFORMATICO DEL HORMIGÓN: program to calculate the sections, not only for obtaining tensions and deformations but also for verifying the Final State Limit.
- Several spreadsheets and programs for specific applications.