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Barrier Replacement Works of the Ruitelán Viaduct A-6 P.K. 424 + 000

Obras de sustitución de pretil del viaducto de Ruitelán A-6 P.K. 424+000

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ABSTRACT

The Ruitelán Viaduct is located on the A-6, was originally built for the passage of the N-VI and was subsequently partially rebuilt and its deck expanded to accommodate one of the two lanes of the Highway. An intervention by emergency procedure has been required, in the right margin of its deck to carry out the replacement of the barrier, due to the deterioration that it presented. For this, the new parapet was designed in accordance with the current regulations regarding containment systems, and the works were carried out applying different construction techniques with the aim of minimizing the effects on the existing structure, as well as the users of this route.

KEYWORDS: Bridge, rehabilitation, barrier, containment systems, hydrodemolition.

RESUMEN

El viaducto de Ruitelán se encuentra en la A-6, fue originalmente construido para el paso de la N-VI y posteriormente fue reconstruido parcialmente y su tablero ampliado, para alojar una de las dos calzadas de la Autovía. Se ha requerido una intervención por procedimiento de emergencia, en la margen derecha de su tablero, para realizar la sustitución del pretil, debido al deterioro que presentaba el mismo. Para ello se diseñó el nuevo pretil, de acuerdo con la actual normativa referente a los sistemas de contención, y las obras se realizaron aplicando distintas técnicas constructivas, con el objetivo de minimizar las afecciones a la estructura existente, así como también a los usuarios de esta vía.

PALABRAS CLAVE: Puentes, rehabilitación, pretiles, sistemas de contención, hidrodemolición.

1. BACKGROUND

The Ruitelán Viaduct (figure 1) is located in the P.K. 424+000 of the highway that connects Madrid with La Coruña (Galicia) and it was built at the end of the seventies to allow the passage of the National Highway N-VI over Arroyo Real, in the municipality of Ruitelán.

Later, it was partially modified at the beginning of the 2000's, enlarging the deck to accommodate one of the two current roadways of the A-6 freeway, specifically the left lane, towards Madrid.

Due to the degradation of its vehicle containment system, it has been necessary to carry out several actions to replace the parapet on the right edge regarding the direction of traffic circulation, with the consideration of emergency works.

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Figure 1. General view once the parapet has been replaced.

2. DESCRIPTION OF THE VIADUCT

The Ruitelán Viaduct (figure 1) consists of nine spans, and has a total length of 430.35 m between abutment joints and a 11.20 meter wide deck. Within this width, the deck holds two areas for the 0.35 m metal parapets on each edge, an inner 1.00 m shoulder, two lanes of 3.50 m each and an outer 2.50 m shoulder. The spans are 27.00 - 29.00 - 28.70 - 66.00 -120.00 - 66.00 - 28.70 - 29.00 - 27.00 m (figure 2).

These lengths correspond to the 1-to-9 spans, numbered in the direction of the increasing P.K. (direction Madrid towards La Coruña), that is to say that abutment E1 is located at P.K. 423+677 and abutment E2 at P.K. 424+118.

The first three spans were rebuilt when the N-VI road, initially a two-way road, was transformed into one of the carriageways of the A-6 freeway, due to the change of plan in that area of the original bridge. The deck of these first three spans consists of two concrete girders, prefabricated and pre-stressed, 1.30 m deep, separated 5.60 m between axes, and an *in situ* concreted slab on prefabricated slabs, with a total 0.25 m depth.

The three central spans correspond to a box section deck solution, made up of 6.00 meter wide segments of variable depth (between 2.00 m in the center of the span and 5.60 m on the pier axis), which was built by the balanced cantilever method. The side cantilever has a minimum depth of 0.20 m on the edge, on which the existing parapet rests.

Originally, this section´s width was 10.00 m and it was extended on both edges of the deck by 0.60 m, to reach the 11.20 m of width, required by the highway.

Finally, the last three spans, 7 to 9, are made up of four prefabricated and pre-stressed girders, with a 1.60 m depth, separated by 2.03 m between axes, which are complemented by a slab *in situ* on prefabricated slabs, with a variable depth, with a minimum of 0.20 m at the end of the deck.

Here also, the deck slab was enlarged by 0.60 m on each side, to reach the necessary width.

The piers belonging to the central span, built by balanced cantilevers, are embedded in the deck, while in the rest of the piles there are elastomeric bearings.

All the piers are hollow-section type. The P4 and P5, embedded in the deck, are 4.00 m rectangular section in the longitudinal direction of the bridge and 6.00 m in the transversal direction. P3 and P6, are also rectangular section, but different dimensions (8.00 m by 3.00 m). Finally, piers P1, P2, P7 and P8 are octagonal in section, 4.00 m in the transverse direction of the bridge and 2.00 m in the longitudinal, and consist of a "hammer" type pier cap on its crown.

The abutments are closed, E1 (from span 1 - Madrid side) was laterally enlarged when the deck was extended and E2 (from span 9 - La Coruña side) was again rebuilt when spans 7 to 9 were rebuilt.

There are joints in the roadway at both abutments and between spans 3 and 4, and 6 and 7.

3. PRESERVATION CONDITION OF THE VIADUCT

The original project of the bridge dates from July 1977 and the enlargement of the deck from 2002. That is, the original structure, at the time of the emergency works, was about 40 years old and the enlargement about 15 years. Both projects were drafted by PROES.

This Viaduct has been inspected [1] in detail on several occasions; the last inspection was carried out in 2014 by PROES,

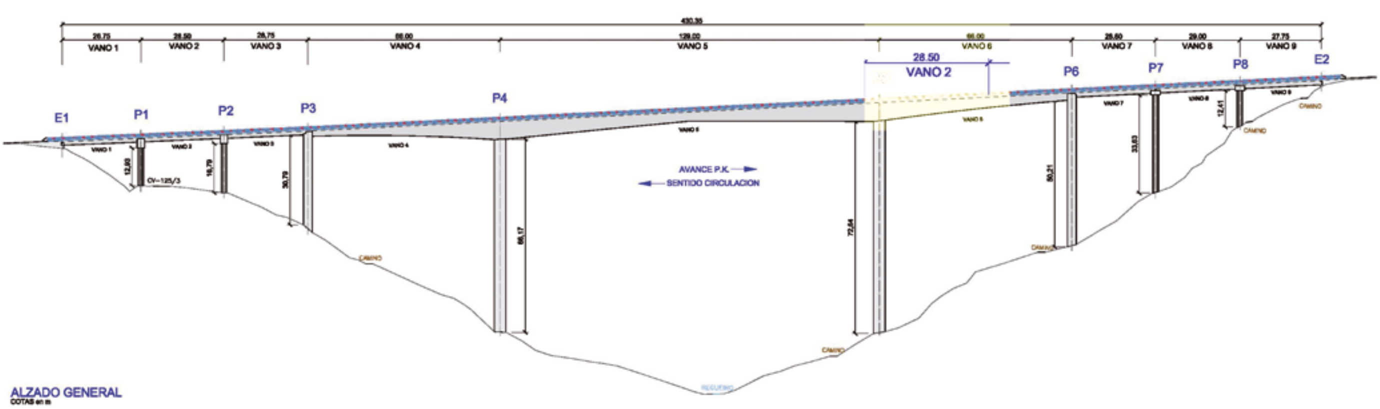

Figure 2. Ruitelán Viaduct´s side elevation.

and the previous one in 2009 by another Engineering Consultant specialized in structures.

Figure 3. Walkway used in detail inspection.

The carried-out inspections included the use of auxiliary means, such as an articulated walkway on a truck, which allows access to the lower part of the deck, as well as checking the status of bearings at the top of the piers (figure 3).

On each of these occasions, a survey of pathologies of the various elements of the bridge was carried out and it was concluded that, at the beginning, the damage did not require an immediate intervention. However, during these inspections, damages were already located in some of the parapets (figure 4).

Figure 4. Detail of deterioration in parapets.

Besides, already at that time, other deteriorations were registered in the concrete of the bands where the parapets are anchored (figure 5).

Figure 5. Detail of strapping damages.

On the other hand, in these inspections it was possible to verify a certain deterioration in the area of the cantilevers of the deck, where the original structure joins the expansion of the deck carried out later (figure 6).

Figure 6. Cantilever status view.

Over the time, the parapets have suffered an increase of their deterioration, basically caused by the aggressive environment in which they are located.

The Ruitelán Viaduct is located in an area of the highway, with very low temperatures during the winter season, which requires the use of de-icing salts on the road, to ensure the flow of traffic through this important connection between Madrid and Galicia (winter roads).

These salts are a source of damage and deterioration for the metallic elements, such as the existing parapets, and for the concrete ones, such as the anchorage band of the parapets, exposed to their contact. In addition, the existence of defects in the waterproofing and the drainage system (drains) for the evacuation of the water that falls over the deck, accelerated the processes of deterioration.

In this particular case, the right-hand edge is the most affected by this damage, due to the slope of the road, which makes this edge of the deck the one that receives the surface water that falls over the pavement.

In a last inspection carried out in October 2015, it was found that the deterioration of the parapet on the right edge of the Viaduct (corrosion, both in the barrier´s posts and in its anchorages) affected just over 50% of the total length of the parapets on that side of the structure (figure 7), and due to these circumstances, the Ministry of Public Works (Ministerio de Fomento) has taken action, through emergency work, to restore the adequate conditions of the containment system.

Figure 7. View of the state of the parapet (2015).

The rest of the pathologies, of minor importance, detected in the mentioned inspections, have been included in a project of rehabilitation independent of the works included in the emergency, to be treated in the future in an ordinary way.

4. MOTIVATION FOR THE ACTIONS TAKEN

The general condition of the parapet, as well as the precarious state of conservation of some of its parts, have led to the need of an emergency intervention, in order to carry out the replacement works of the parapet in the short term, to re-establish appropriate conditions of the containment system in the viaduct.

Moreover, according to the current regulations, the intervention to replace the parapet requires that the new parapet to be installed complies with the conditions of the CE label. Meeting this requirement means that not only does the parapet comply with this certification, but also that, in accordance with Ministry of Public Works Circular Order 35/2014 [2], the structure in the parapet's installation area must be adapted so that it is the same as those used in the containment system tests.

This regulatory framework makes practically inevitable the demolition and subsequent reconstruction of the edge of the deck, where the parapet is fixed, in order to adapt its geometry and reinforcement to those contemplated in the parapet validation tests.

In the particular case of this viaduct, due to the state of deterioration related to the edge area of the previously extended deck (figure 8), it has been considered necessary to extend the reconstruction of the deck to a larger area than that strictly necessary for the installation of the new CE-marked parapet.

Figure 8. View of the state of the right edge of the existing extended deck.

In the face of this intervention, an estimate was made regarding the minimum service life to be fulfilled by the reconstruction of the deck, taking into account that originally, the fulfilment of a service life requirement for this bridge had not been taken into account, considering that at the time of its construction, the applicable regulations did not require it.

It should be highlighted that this action concerns a small part of an existing structure, and is located in one of its elements, the deck; therefore, it is not technically reasonable to apply service life criteria for the action, which is inconsistent with those applied to the rest of the structure.

Assuming that, as a large structure, it is reasonable to presume that the service life should be at least about 50 years, and taking into account its current age of 39 years, the rebuilt part should have a minimum service life of 11 years.

It was verified by means of the Chloride Penetration Model (Annex 9 from EHE-08 [5]), that, according to the characteristics of the reconstruction to be carried out, this requirement was met.

4.1. Selection of the parapet according to regulations

The election of the parapet (safety barrier placed on the edges of bridge decks and passage works, wall coronations and similar works) to be placed on this Viaduct is carried out in accordance with the indications of the O.C. 35/2014 [2] and the PG-3 [6].

For this purpose, two issues are taken into account: the type of accident risk (very serious, serious or normal) and the tested behavior of the parapets (transverse displacement characterized by dynamic deflection and working width).

The risk of accident is determined by the characteristics of the road (the Average Daily Traffic Intensity (IMD), or the one corresponding to heavy vehicles (IMDp), the curvature of the road's layout, the project speed, etc.) and those concerning the obstacle to be crossed (for example, if it crosses over a railroad, river, or a high IMD road, the fall height, etc.).

The dynamic deflection (D) is the maximum transverse displacement produced during the impact of the system face closest to the vehicle (figure 9).

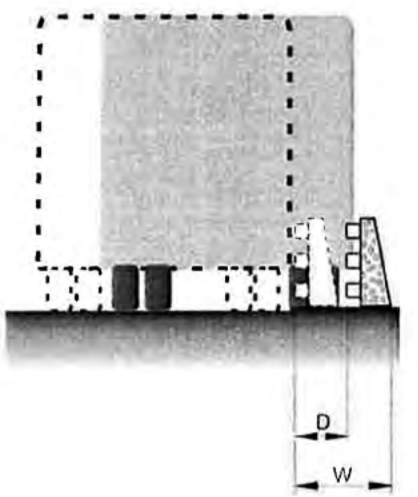

Figure 9. Dynamic Deflection (D) and Working Width (W) (Source: OC 35/2014 Mº Fomento).

The working width (W), is the distance between the face closest to the vehicle before impact and the furthest lateral position which, during the impact, reaches any essential part of the containment system assembly and the vehicle (figure 9).

In the case of the Ruitelán Viaduct, according to IMD data and the features of this bridge, it is considered a very serious accident risk and a H3 type parapet is adopted, whose dynamic deflection is 0.60 m, with a working width of 1.00 m, according to the manufacturer's specifications of the approved parapet used in the works.

4.1.1. Type of risk

The risk of accident has been qualified as “Very Serious” due to the fact that this Viaduct has the characteristics required by the OC 35/2014 [2] in terms of "Outstanding structures, understanding as such those with spans of more than 200 m, as well as those of lower length saving singular areas (large water courses, reservoirs, valleys of very difficult access)"; specifically, this Viaduct has an more-than-400 meters length and a maximum height above the ground of more than 70 m.

4.1.2. Containment level

As far as traffic is concerned, according to data from the two closest stations, provided by the State Roads Unit in Lugo, the IMD and IMDp are as follows (table 1):

TABLA 1.
IMD and IMDp

Station	K.P.	IMD total	IMD heavy
LE-220-3	428	3361	932
LE-221-2	412	3657	1054

These data have been updated, taking into account the increase in traffic from the date of data collection, up to the time of the performance.

The recommended level of containment for the resulting IMDp (< 2000) is H3.

The H3 type parapet chosen, in accordance with the UNE-EN 1317 [3] standard, has been tested by the manufacturer under two different impact situations, in order to obtain the CE label for it:

Figure 10. TB61 Tests
(Source: Industrias Duero - ASEBAL)

- Test TB61: A heavy non-articulated vehicle, with a mass of 16000 kg, crashing at a speed of 80 km/hour with an impact angle of 20° (figure 10).

Figure 11. TB11 Tests
(Source: Industrias Duero - ASEBAL)

- TB11 test: A light vehicle, with a mass of 900 kg, crashing into it at 100 km/hour, also with an impact angle of 20° (figure 11).

4.2 .Conditions to be fulfilled by the parapet

The parapet must satisfy two conditions:

- Impact severity index, which can be A, B or C, depending on the values of the ASI and THIV indicators.
- Working width class (W1 to W8), depending on the working width (m).

In the case of the selected parapet H3, the Severity Index is B and the Working Width Class is W3 (< 1.00 m).

The dynamic deflection, D, of the H3 parapet is 0.60 m; for this reason the width of the band has been increased to 0.56 m, so that the distance between the face of the parapet on the side of the road (where the vehicle would impact) to the outer edge of the deck is 0.63 m, higher than this D = 0.60 m.

Regarding the severity index, and in accordance with the UNE-EN 1317 [3], it is related with two indicators that are calculated from the results obtained in the light vehicle impact test (TB11); these are the acceleration severity index (ASI) and the theoretical head impact speed (THIV). This severity index is classified into three classes, A, B and C, with A being the least severe for the vehicle occupants.

5. DESCRIPTION OF THE PROJECTED AND EXECUTED WORKS

The works designed and executed consisted basically in replacing the deteriorated parapet with a new one, which had the mandatory CE label, and, for this purpose, it was necessary to demolish the existing cantilever and rebuild it with adequate geometrical and resistant conditions.

Due to the poor condition of the structure in the enlarged area several years ago, the repair was extended to that area, in order to avoid the need to carry out the new reconstruction linked to a deteriorated area.

The new parapet, with a total length of approximately 440 m, required the construction of a band of slightly larger dimensions than the existing one, so the deck was extended by 0.21 m on the right side, to obtain a band of 0.56 m. As for the band's depth, it was required to have 0.41 m, in order to hold correctly the band's standardized reinforcements and the reinforcements in the anchorage points of the parapet's uprights, as well as its anchorages.

The materials used in the reconstruction of the deck have been HA-35/B/20/IV+F type concrete of high initial resistance with additives (air-entraining, super-plasticizer, retardant and setting stabilizer) and the steel for the reinforcement has been B 500 S type.

The checks of structural behavior were carried out considering the current IAP-11 [4] and EHE-08 [5] codes. It should be highlighted that this current regulation differs from the applicable regulations at the time of designing the original structure and the 2002 extension.

In the central spans (spans 4 to 6) the vertical load increases (both permanent loads and imposed loads) are very low (less than 5%), while in the other spans, this increase exceeds 10%.

For the verifications related to the accidental load, due to the impact on the parapet, in accordance with the IAP-11 [4], the requests provided by the manufacturer of the parapet with CE label have been considered (tested according to the current regulation UNE-EN 1317 [3] to obtain the certification).

The actions corresponding to the maximum shear force and the maximum bending moment produced by the impact in the worst direction, and with a 20° direction, as well as the forces concomitant with these maximum, have been considered.

These forces were found to be:

- Maximum bending moment scenario:

TABLE 2.
Parapet actions-maximum bending moment

MOSA 20 PARAPET(H3)						
MAXIMUM BENDING MOMENT						
Comb.	Force	Angle (°)	Long. F (kN)	Trans. F (kN)	Long. M (kN·m)	Trans. M (kN·m)
10	Dist.	90	0	377	0	245

- Maximum shear scenario

TABLE 3.
Parapet actions - Maximum Shear

MOSA 20 PARAPET(H3)						
MAXIMUM SHEAR						
Comb.	Force	Angle (°)	Long. F (kN)	Trans. F (kN)	Long. M (kN·m)	Trans. M (kN·m)
5	B. inf.	90	0	452	0	158

- UNE 1317 standard [3] scenario, where the impact occurs at 20° of inclination:

TABLE 4.
Parapet actions – 20° direction

MOSA 20 PARAPET(H3)						
MAXIMUM STRESS AT 20° ANGLE						
Comb.	Force	Angle (°)	Long. F (kN)	Trans. F (kN)	Long. M (kN·m)	Trans. M (kN·m)
2	B. inf.	20	205	75	72	26
7	Dist.	20	127	46	83	30

After the verifications have been done with the available data, it was concluded that the structure complies with the mandatory safety level.

On the other hand, due to the fact that there are three zones of different deck typology, it was necessary to define a general action, which was later particularized for the features of each one of them.

The projected works include the following general actions (figure 12):

- Scarifying (milling) of the existing pavement in a width of approximately 3.00 m.
- Partial hydrodemolition of the upper face of the deck along the right-hand side, preserving the extreme fastening band of the current parapet.
- Removal of the existing parapet.
- Cutting of the edge of the deck (extreme fastening bands of the existing parapet) into "modules", whose weight and dimensions would allow their subsequent transport by truck.

- Anchorage of the lower reinforcement by means of chemical anchorage on the side face of the cut deck edge.
- Formwork, by means of an auxiliary carriage, of the bottom of the deck, and the side of the new band.
- Placement of reinforcing bars of the upper face of the deck to be rebuilt, and of the new band.

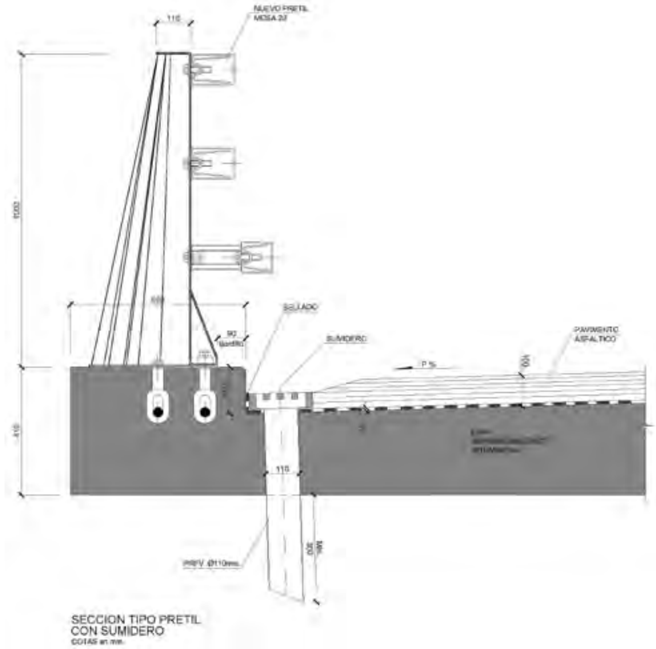

Figure 12. Typical Section.

- Concreting of the deck area to be rebuilt, and of the band.
- Placement of the new parapet, including extreme transition zones outside the deck (abutment zone).
- Installation of new drains.
- Waterproofing of the deck.
- Paving of the deck area between the existing pavement and the band.
- Placement of new expansion joints between decks.

We have the following specifics of these actions for each type of structural section:

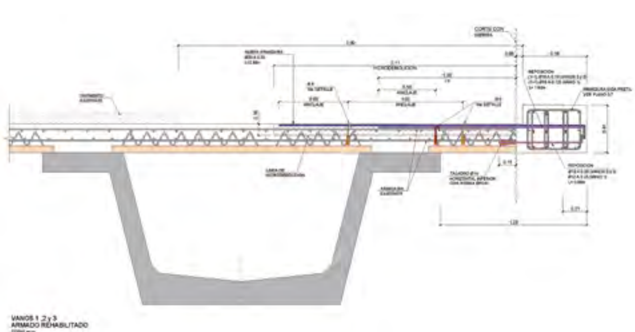

Figure 13. Section type performances spans 1 to 3.

The most important particularization is the definition of the area to be hydrodemolished. In the case of the standard section of spans 1 to 3, the width was 2.11 m, and its depth was 0.10 m (figure 13).

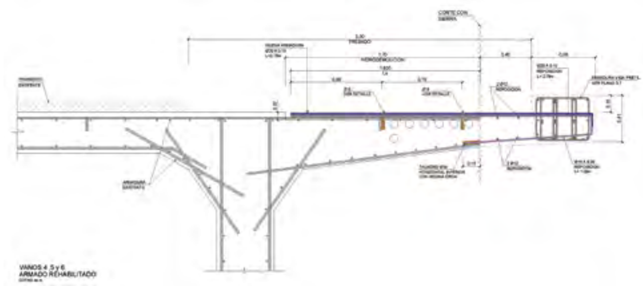

Figure 14. Section type performances spans 4 to 6.

In the standard section of spans 4 to 6, the width was 1.70 m, and its depth was 0.07 m (figure 14). The real depth was variable, since the different qualities of the concrete to be demolished and the existence of the sheaths near the hydrodemolition zone, did not allow to adjust to the theoretical level foreseen.

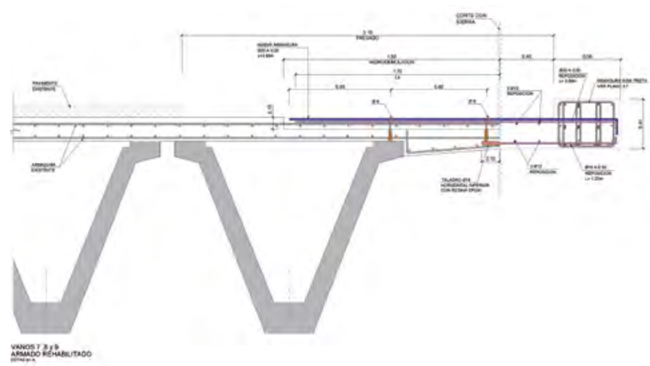

Figure 15. Section type performances spans 6 to 9.

Finally, in the case of the standard section of spans 7 to 9, the width was 1.80 m, and its depth was 0.10 m (figure 15).

The barrier is a metallic parapet that is fixed to the deck in the zone of the band by means of some anchorages that remain embedded in the same one (figuras 16 and 17).

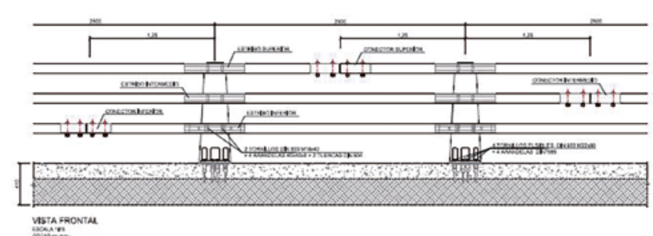

Figure 16. Top view of new parapet with CE marking.

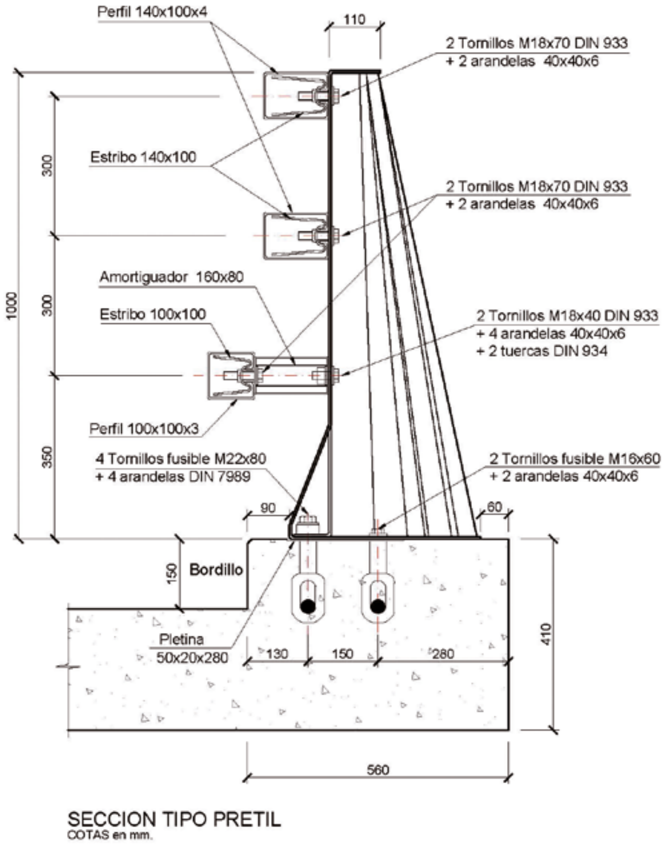

Figure 17. New parapet section with CE marking.

6. EXECUTION OF THE WORKS

Once the necessary traffic re-routing had been carried out and the necessary means had been put in place to guarantee safety, work began, starting with the milling of the existing road surface in an approximately 3.00 m width). (Figure 18)

Figure 18. Milling the pavement.

The milling works, as is usual in this type of intervention, affected a slightly greater thickness than the theoretical one, due to the appearance of existing re-pavement layers.

The works were carried out in successive phases, which allowed different works to be carried out simultaneously in different areas of the bridge, in such a way as to minimize the execution time.

Figure 19. Partial hydrodemolition of the deck.

Next, the hydrodemolition (figure 19) of the upper face of the deck was carried out in a lateral strip of different thickness and width, depending on the area of the deck (spans 1 - 3, 4 - 6 or 7 - 9), as already mentioned (preserving the extreme fixing band of the current parapet).

For the hydrodemolition, a robot was used to control more efficiently the depth of the demolition carried out (figure 20). In order to avoid environmental problems, the water used in these tasks was collected and treated, before being poured into the bed of the Arroyo Real stream.

Figure 20. Hydrodemolition Robot.

The solid residues of this hydrodemolition were collected on the same deck and later removed (figure 21).

Figure 21. Cleaning hydrodemolition deck residues.

This hydrodemolition system left the reinforcement of the upper face visible, without deteriorating them, so that the new reinforcement required by the CE marked parapet could be overlapped with them (figure 22).

Figure 22. Existing reinforcement exposed.

The hydrodemolition works had to be adjusted on the fly, due to the diversity of concrete qualities found along the Viaduct, which is why in some areas a revision of the hydrodemolition surfaces was carried out with a localized demolition using a pneumatic hammer, in order to reach the foreseen demolition thicknesses and ensure a correct connection between existing and new concrete.

Figure 23. Detail of mechanical couplers.

The couplers used to overlap the reinforcements used in the panel expansion work carried out in 2002, were also exposed (figure 23).

Figure 24. Existing and exposed post-tensioned sheaths.

It should be noted that, in the spans built by balanced cantilevers, hydrodemolition left several post-tensioning sheaths visible (figure 24), some of them with certain deterioration (figure 25 and figure 26) which, although they did not affect the cables, were repaired by means of sealing injections, improving the durability of the work by protecting the cables contained in them.

Figure 25. Post-tensioned sheath details withdeterioration.

The mentioned damages in certain sheaths were originated by a defect in their filling, concretely the lack of grout in some areas, which caused that when carrying out the hydrodemolition of these sheaths, they were deteriorated and allowed to visualize their lack of filling.

These deteriorations were repaired by cleaning the affected areas, both the sheaths themselves and the cables that had been seen, by manually brushing these elements, and then injecting grout.

Figure 26. Deteriorated sheath sealing boxes.

This repair was carried out in several areas, since this type of deterioration was detected in different positions.

A specific product was applied for the sealing, with the characteristics required for this type of performance.

To confine the area to be injected, wooden boxes were assembled and sealed around the perimeter with repair mortar (figure 26); a ribbed metal sheet was then laid out to ensure roughness between this paste and the concrete to be placed in the rest of the span. Finally, a sheet of plywood was placed between the sheaths and the passive reinforcements that cross over them, to close the area to be injected and to be able to perform a correct injection of the holes in the sheaths.

Figure 27. Sealing of deteriorated sheath areas.

Once the enclosure was formed, a grout was injected with a specific product (CONBEXTRA LC), through some holes made in the plywood sheet (one hole for the grout injection and another one for the air exit control).

In order to avoid displacement of the phenolic sheet during injection, a counterweight was placed on it.

Finally, once the plywood sheet was removed, the upper face was brushed, in order to guarantee the necessary roughness to produce the adherence with the concrete on it (figure 27).

Later, the existing parapet was dismantled and, with a radial cutting machine (figure 28), the band located at the end of the deck was removed. First, some cuts were made in a transversal direction to the longitudinal axis of the deck, separated between 3.50 and 4.00 m, and a couple of anchorages were placed to fix some slings to remove the cut "module".

Figure 28 Radial Cutting Machinery.

Finally, a parallel cut was made at the edge of the deck to separate the "module" from the rest of the deck, and remove it (figure 29).

Figure 29. Removal of cut "modules".

On the side face of the edge of the cut deck (figure 30 and figure 31) some holes were made to anchor the corresponding bars to the lower face of the reconstructed deck using epoxy resin.

Figure 30. View after radial cutting of the strap

Figure 31. Detail of the radial cut of the strap.

Subsequently, using a formwork traveler (figure 32 and figure 33), the formwork of the lower face of the deck to be rebuilt was installed and the one at the side of the edge band to fix the parapet, was assembled. Two travelers were arranged to work in two sections simultaneously.

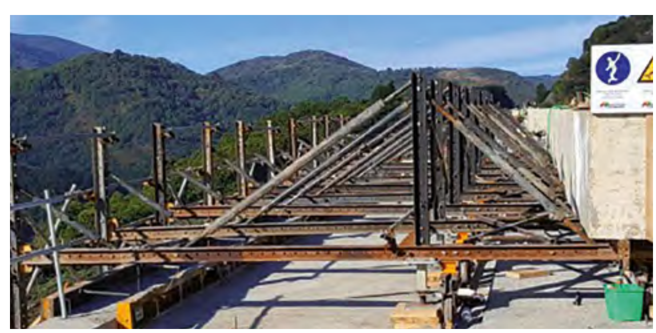

Figure 32. View of the formwork traveler.

Figure 33. Traveler Positioning View.

The formwork traveler, which also included the necessary working platforms, was arranged in position with the help of a crane (figure 34).

Figure 34. Overview of traveler positioning.

Subsequently, the band reinforcement was assembled, together with the plates and anchorages of the parapet uprights (figure 35), and the reinforcement of the upper face of the slab.

Figure 35. Anchorage of the parapet.

The new reinforcing bars on the upper face overlapped with the existing ones and, to prevent displacement, a series of U-shaped hooks were chosen (figure 36), fixed by holes and epoxy resin to the deck, with a separation of 0.30 m.

Figure 36. Storage of hooks for fixing bars.

It is worth noting that, when the existing reinforcement was discovered by the hydrodemolition, several situations different from those foreseen were found, either with separations between bars different from those theoretically known, as well as some areas with reinforcement of different diameters.

Figure 37. View of the concreting process of the deck and the strap.

Once the reinforcement and the anchorages were in place, the concrete was poured as a whole for the band and the deck (figure 37).

To remove the formwork of the reconstructed cantilever and the fastening band of the new parapet, the conditions of age and minimum resistance of the concrete in which it could be made, were determined. According to the carried out tests, a minimum resistance of 18 MPa at 24 hours was determined (about half of f_{ck} = 35 MPa) to remove the cantilevers at 36 hours, and 20 MPa at 36 hours after the concrete was poured to remove the formwork at that moment. For the concrete quality control, it was necessary to add two more pairs of specimens to the usual ones, one for the testing at 24 hours and another for the testing at 36 hours.

In the area of spans 4 to 6 (box-type section), the reconstructed deck´s upper face was leveled with a layer of lightweight concrete (with an aggregate of Arlita®-type expanded clay). The origin of this need was in the deformation of the deck, which required, in order to achieve the correct level, to fill the space between the lower face of the pavement and the upper face of the structural concrete section. In order to limit the increase of permanent loads on the structure, a solution using a regularization concrete with a light aggregate was chosen.

The drains and vertical drainage pipes were also installed (figure 38), having provided the necessary space before the concreting of the cantilevers, to avoid damaging the reconstructed slab by drilling it once it was built.

Figure 38. View of newly installed parapet.

Next, it was carried out the waterproofing of the reconstructed deck area (figure 39). For this purpose, an adhesion irrigation was applied under the wearing course, consisting of a modified cationic emulsion (C60BP3 ADH) with a dosage of 8 kg/m², completed with a waterproofing treatment consisting of an anionic bitumen emulsion (COMPOPRIMER) with 0.3 kg/m² and a bituminous mortar (AMIFLEX) with a dosage of 3 to 4 kg/m².

Figure 39. Rebuilt waterproof deck view.

Before proceeding with the execution of the pavement layer, the new parapet was installed (figure 40).

Figure 40. View of the newly installed parapet.

The parapet is fixed by nuts to the screws (which act like a fuse in case of impact) in the anchor plate embedded in the band (figure 41).

Figure 41. Detail of fixing of the new installed parapet.

Finally, some bands were executed for the embedding of the parapet in the wing walls of both abutments, finishing off the containment system at both ends (figure 42).

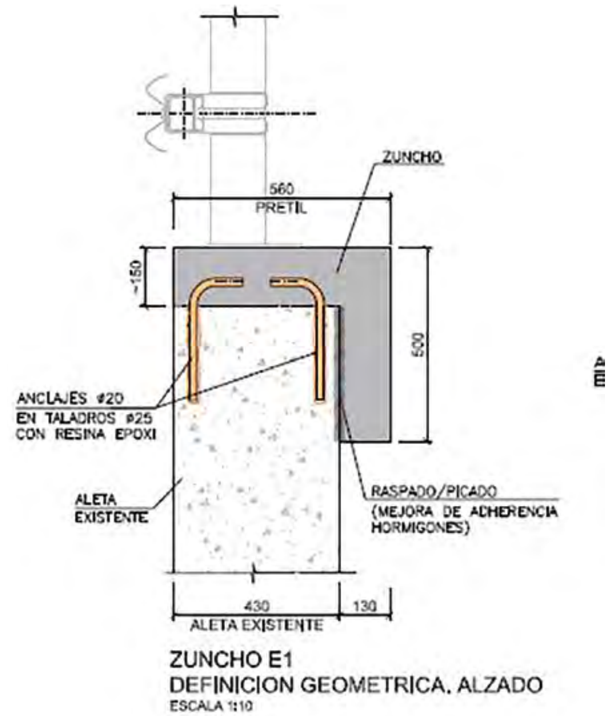

Figure 42. Strap in Abutments.

For this purpose, the anchoring of the parapet in the area was solved in both abutments by embedded bands with pins anchored to the existing wing wall of the parapet itself, in order to generate an area with the needed geometric dimensions and the required assembly for the fixing of the parapet (figure 43).

Figure 43. Concrete straps in the abutment area.

Completing the works, the paving over the waterproofing was done. As for the pavement, it was resolved with a layer of 3 cm-thick bituminous mixture BBTM 11 B PMB 45/80-65 (M-10), and a 7-cm-thick layer of bituminous mixture AC 22bin BC50/70 D (D-20) spread over the deck, in correlation with the arrangement of layers in the main way.

The road marks were also restored and new joints were installed to replace the sections that had been removed during the works. In some of the joints, due to their deterioration, the area affected by the works was also replaced the rest of the joint.

Although it is not part of the structural solution, it is worth mentioning, due to the importance of this type of work, the planning of the different traffic provisional re-routings, which is necessary for the development of these works.

During the course of the work, partial traffic deviations were required, affecting the Viaduct´s part of the roadway, but also, at times, a complete deviation of the Viaduct's traffic was necessary, which required the traffic to run through the other roadway.

At the beginning it was decided to propose the option of cutting one lane, because the maintenance of both lanes during the development of the work was considered unfeasible, since, imposing a narrowing of both lanes, leaving each one at 3.00 m, and the shoulders at 0.70 m, did not leave the necessary available space for the work´s correct development, with serious risk for the safety of the users and the work's personnel.

It was therefore decided to close one lane of the roadway, leaving only one operational lane, although a wider one. The dimensions for lanes and shoulders on a provisional basis during the development of the works after the partial cutting of the roadway, were as follows: outer shoulder: 1.50 m, provisional lane: 4.00 m, inner shoulder: 1.00 m and curb: 0.35 m.

In total, the circulation area was 6.85 m wide; since the original roadway had a total width of 11.20 m, a 4.35 m wide strip was left for the works. The separation between both areas was made by an anchored concrete TD-1-type barrier.

This solution was considered suitable, since 6.50 m (6.85-0.35) was a sufficient width for special transports, being also a straight section.

Subsequently, it was necessary to cut off the entire roadway (Transfer), since once the work had begun, a study of the main risks was carried out. This study analyzed all the phases in which it was possible to keep the roadway traffic in the fast lane of the viaduct, and the phases in which it was necessary to cut off the traffic, for the safety of the viaduct itself, of the workers and due to the nature of the work to be undertaken.

The study concluded that during the cutting phase and the reconstruction of the cantilever of the deck by means of carriages, it was not possible to keep the roadway open to traffic. This is because during the operation of the available cranes in the area, with sufficient capacity to move the sections that were being cut from the viaduct, (with which the pieces were held by slings that were later lifted to the truck that removed them), the lane that was originally prepared for traffic was inevitably invaded, so it was concluded that it was necessary to occupy the entire roadway.

In addition to all this, once the superficial hydrodemolition of the deck´s strip that needed to be discovered was carried out, some sheaths of the pre-stressing of the deck were uncovered. As already mentioned, a certain state of deterioration was observed in some of them, which also made it advisable to release the traffic of that roadway, during the period in which the structure was being repaired.

For all these reasons, it was concluded to adopt the complete cut-off of traffic on the left side of the A-6 in the affected area, making the beginning of the complete cut-off of the road concur with the end of the summer season, avoiding therefore to interfere with this time of year, when the traffic is more severe.

Since the roadways of the freeway run at different levels in this section, the deviation (Transfer) was arranged between the k.p. 422+400 and 429+900, where the adjacent median strip crossings were located closest to the section under construction (figure 44). All the traffic passed through the right-hand roadway, in both directions, with speed limited to 80 km/h. This did not cause any traffic jam problems, nor did it lead to any significant traffic incidents.

Figure 44. Traffic deviation view.

Once the transfer was carried out, it was found that a large number of drivers did not strictly respect the installed site signaling, not reducing their speed. Therefore, prefabricated transversal bands were fixed to force into reducing the speed in both directions, just before the traffic diversion section, in order to improve the safety of workers and road users.

Below there are some views of the completed structure, from both abutments and from below the Viaduct (figs. 45, 46 and 47).

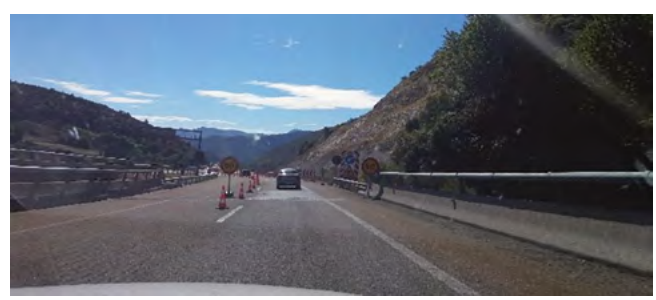

Figure 45. View from Madrid Side Abutment.

Figure 46. Bottom view of rebuilt deck.

Figure 47. View from Galicia Side Abutment.

WORK DATA

Contract execution Budget:
1.210.884,97 €

Timetable for the execution of the works:
26 weeks.
With a stop in summer for 7 weeks due to traffic maintenance needs, resulting in a real total time of 19 weeks for the works.

Main work units:
Parapet CE marked: 440 m
Milling pavement: 128 m^3
Hydrodemolition: 75 m^3
Radial cut: 430 m
Formwork: 700 m^2
Reinforcement steel: 55 tons
Concrete HA- 35: 210 m^3
Drills for anchoring bars: 11,000 units

Promoter:
U.C.E. Lugo - D.C.E Galicia Mº de Fomento.
Construction Company:
COPASA

Construction project and technical assistance to the management of the works.
PROES, Consultores S.A.

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