



*Treto bridge.*

## Treto Bridge Refurbishment (Cantabria, 1905-2016)

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### ABSTRACT

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The paper delves into the process of refurbishment of an old metal bridge (year 1905) located in a marsh (mouth of the Ason river, Cantabria) of high environmental value. The repair was necessary to guarantee the structural safety of the bridge, which serves a national road (N-634). At the same time, it was necessary to preserve its cultural values and, during the work, to fulfill the environmental requirements.

The text emphasizes the importance of having a good record of information on the bridge in order to plan a good intervention. The results confirm that the previous studies have been useful to project and execute a deep repair, respecting the cultural landscape of the estuary.

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### KEYWORDS

*steel bridge, bow-string, refurbishment, cultural landscape*

## 1. PREFACE

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This research exposes how was made the refurbishment of Treto Bridge during the summer of 2016, and the damages that caused it. It illustrates the cases of adapting old bridges to nowadays user service requirements, not only attending to the construction functionality and also to design and execute an intervention coherent with the cultural value of the public work.

In Spanish context of intervention in old public infrastructures in use, the developed solution can be qualified as conventional. This happened with other bridges with similar typologies as well as Coria's (Cáceres, Alagón river, repaired in 2003), Toro's (Zamora, Duero river, strengthen in 1980 and 2017), or Villafer's (Leon, Esla river, repaired in 2016)<sup>1</sup>.

In Treto's case, the solution had been motivated because of two aspects: an immediate one, derived from the economic and administrative constraints that surrounded the study and the intervention; and the other with deeper meaning, that roots in the cultural patrimonial consideration of public infrastructures, in the training about of responsible technicians for carrying out these actions and, ultimately, in the sensitivity of citizenship in general on the protection and care of the landscape and public infrastructures<sup>2</sup>. However, during the long process of processing that concluded with the repair always kept in mind that it was facing a public infrastructure of undeniable value and high responsibility in the creation of the cultural landscape of the place. For this reason, a life study of the bridge was carried out, which ranged from its origins to the present.

The documentation<sup>3</sup> generated for the processing and construction of the bridge is plentiful and varied, and has allowed facing refurbishment by having extensive knowledge of both the physical elements that constitute the bridge (foundations, supports, parabolic and rotating sections, etc.) and its maintenance, as well as the contextualization of these at the time it was projected, built and enjoyed.

## 2. TRETO BRIDGE CHARACTER

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### 2.1 LOCATION

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Treto bridge allows the N-634 national road to save the mouth of the Asón River between the municipalities of Colindres and Bárcena de Cicero, in Cantabria. The zone of the littoral where the bridge is located corresponds to the second largest estuary in the region protected by environmental legislation through the ZEPA, LIC and Natural Park (Parque Natural de las Marismas de Santoña)<sup>4</sup>.

The presence of the bridge in this place is fundamental to understand how, from the drawing of the historical roads, the current outlook of the terrestrial communications of Cantabria has been reached. The construction of the bridge was brewed between 1880 and 1905, but the conditions for the work date back to the middle of the 19th century and must be understood in the context of a territorial conflict due to the preponderance of an old commercial route, the connection with Castilla by the port of Los Tornos, facing up the modern one that runs parallel to the coast by the traditional "Camino de la Costa". This path was gradually adapted and improved until it became a highway (Highway Law of 1857). Over the years, this route that runs roughly parallel to the Cantabrian coast became the link between the regional spaces of northern Spain, whose coastal strip ended up concentrating a thriving urban and industrial activity.

### 2.2 TYPOLOGY

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It is a metallic structure formed by two main metallic sections of the bow-string type or arch supported by the deck, with variable height along the span. Both lateral elevations are formed by an arch, the lower deck, the vertical uprights that suspend the deck of the arch and a system of triangulation diagonals. The arches are braced together by vertical lattices placed transversely limiting the vertical gauge. In the cross section stand the resistant elements of the slab, formed by domed plates supported on the strut.

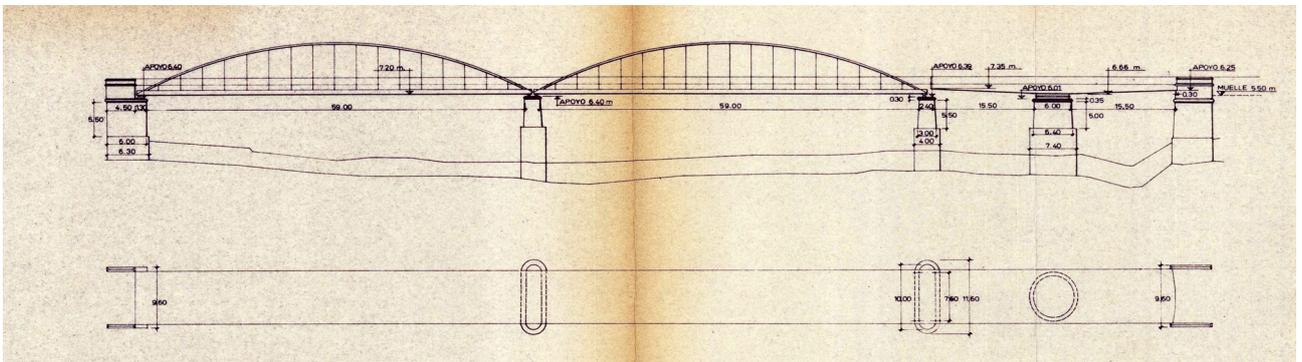


Figure 1.  
General view of the bridge at its site

Figure 2.  
Plan and elevation of Treto Bridge

The substructure is formed by buttress and piers of ashlar masonry, two of oval plan and a third circular on which rests by its middle point the board of the third section, different from the previous ones, formed by two main beams of full soul, ten transverse joists and 8 crossbeams, all these elements with double T section. This part was arranged so that, and until 1940, it was possible to rotate on the ring gear housed in the circular pile and placed perpendicular to the road, allowing this way the passage of boats.

All metal elements were joined by rivets. The total length of the bridge is 161,740 m., Each parabolic section measures 61.84 m and the swivel section 38.00 m. The width of the road is 5.50 m and that of the cantilevered platforms arranged on each side for pedestrian traffic is 0.80 m.

### 2.3 HISTORICAL BACKGROUND OF THE BRIDGE

The bridge was the answer to the demand to solve a need for passage, a requirement that was initially covered by a boat, which has been documented since the 15th century. Towards 1865 the boat, property of the State, was a wooden barge that slid helped by a cable from coast to coast, an expensive and slow system, stopped by the frequent adjustments, winds and tides that interrupted the service.

On that date the width of the estuary had already been reduced by the placement of breakwater, an action that provoked the angry protests of the neighbors<sup>5</sup>.

To alleviate the inconvenience caused by the transit of the boat and simultaneously appease the protests, the provincial engineer designed an iron bridge supported by two fixed turning axes in the ashlar masonry buttress and in intermediate supports formed by metal plate bearings of circular section. It had a total length of 170 m. divided into seven sections and a width of 5.30 m.

It was a floating bridge that had a turning mechanism to allow the passage of boats that traced the estuary to the port of Limpias. The floats, ten in all, served as piers, and on them were placed four longitudinal beams and transverse bracing beams that supported wooden beams on which were fastened planks that formed the floor of the bridge. The possibility of turning allowed a mobile section of the board, 16

m long, to be placed perpendicular to the bridge to allow the passage of boats. The opening and closing process used in certain circumstances the force of the tide and was calculated not to exceed twenty minutes. The reason for designing a mobile bridge was not to impede the navigation to this modest port of Limpias, whose economic interests are skillfully represented and consummated in themselves explain the typology of the current bridge<sup>6</sup>. The building of this provisional floating bridge was suspended at the beginning of the Refurbishment. The new criteria in the field of public works meant that the State decided to adopt the solution of a fixed iron bridge without a rotating section, and with this criterion the draft was commissioned. However, the one that was sent from the province included the revolving section. The reading of the voluminous file of this procedure allows to follow an exciting technical and political debate that illustrates the deep implications of public works in general and bridges in particular, beyond the decision on one or another type or material.

The project finally approved, dating from 1890, was completed in two fixed sections of 61.48 m in length each and a swivel section of 38 m. The width was 9.90 m for the passage of carriages, and had two cantilevered pedestrian platforms supported by corbels, 0.75 m wide in the fixed part and 1.42 m in the mobile.

The turn was possible because the section was based on a circular pier in whose center a vertical axis of wrought iron was embedded. To verify the movement, twelve conical casting wheels were arranged on which the section was fixed, aided by circular wrought iron discs, whose axis was supported by a double ring, which rolled on a hollow box attached to the ashlar masonry pier. The designer described the system as simple and effective, capable of being operated by a single person in a few minutes.

In this combination of typologies, of which no other example has been found in the abundant literature consulted, lies the structural singularity of the bridge. With the definitive approval of the project, the building was auctioned, which were awarded to the Mieres Factory, one of the two that at the end of the century existed in Spain producing the Martin-Siemmens steel<sup>7</sup>. In 1893 the construction of the supports ended, for which it was necessary to use the foundation

system by means of compressed air caissons, looking for support rock, which was not reached, under the layer of dense sands. The assembly of the metal structure took place in 1904; the one corresponding to the fixed sections was manufactured in Mieres, and that of the mobile section came from the Belgian workshops of Angler-Tilleur in Liège. This explains the differences in the material of the sections, the fixed ones are formed by rolled irons while the mobile one is made of steel, with different nominal elastic limits (204MPa and 286MPa).

## 2.4 TRETO BRIDGE IN THE SPANISH CONTEXT

In Spain from the late nineteenth century and until the 1920s several bow-string bridges were built for road, being this solution a common typology. The first bridge with this system built in Spain was the one of Prado on the river Pisuegra, in Valladolid, a single section of 67.70 m of span, and inaugurated in the year 1865. It was designed and built by J. Henderson Porter, an English manufacturer of metal bridges. In the following years different models and patents were known. Little by little, as the experience, the better knowledge of the structural performance and the increase of the quality of the metallic material, typologies and models were refined, so that at the end of the century they were limited to a single model with few variants.

The engineers of the time called these bridges with the expression "bridges of parabolic beams", a variant of the Pratt beam. They used to be of equal lengths - like the projected fixed solution for Treto - with a maximum height of the beam between 1/7 and 1/8 of the span. Among the engineers debated on the advantages and disadvantages, giving positions found, as represented by Pablo Alzola who aesthetically rejected this typology, or that of Joaquín Pano, the great defender of the bow-string, a model that preferred in front of the lattice, because with equal span, the second increased the own weight a lot<sup>9</sup>. The engineer Pano, who was assigned to the Public Works Headquarters of the province of Huesca, defended this structural solution until it reached the confrontation with the Spanish public administration

of public works. The first was built in Monzón, on the Cinca river, in 1880, and others followed on the Alcanadre and Esera rivers.

In general, it can be said that resorting to metallic solutions of this or another type was possible due to the conjunction of aspects such as the availability of a material (iron / steel) that gradually became more aware of its static and dynamic behavior, the existence of factories in Spain able to produce it in quantity and with the necessary quality or the speed for the assembly of the sections in work.

## 2.5 EVOLUTION OF TRETO BRIDGE

The bridge entered service in 1905. Since then the structure has been the object of several conservation actions. Of these, it is worth mentioning the one made in the 1960s, because it repaired and / or replaced many original elements, and also because it motivated the drafting of a project to build a new bridge upstream and parallel to the existing one. Initiated this work in 1970, the execution of buttress caused the appearance of cracks and fissures in the metal bridge. Paralyzed the construction while a solution was studied, it was never resumed, largely because in the scenario of road planning emerged the construction of the Cantábrico highway and its solution to cross the estuary via a viaduct with two cable-stayed sections from three piers located on the axis of the board. The contrast between the two bridges, which can be seen in figure 1, constitutes a relevant element characterizing Cantabria's cultural landscape.

The decision to maintain the bridge, now for the maintenance of the roads of a national road with local traffic, motivated the approach of its refurbishment. The first initiatives in this sense date from 1993, but different administrative and economic avatars have meant that this has not been possible until the year 2016<sup>9</sup>. The works finally executed, whose thread of processing started in 1993, have consisted, as essential in reinforcing, repairing and / or replacing each element depending on its status and expected requirement.

## 2.6 THE BRIDGE, EXPRESSION OF CULTURAL VALUE

The Treto bridge can be studied taking into account the value categories that Fernández Ordóñez proposed to the Council of Europe in the eighties, and which are still valid to analyze historic bridges and their possible refurbishment.

Its value is nourished not only by functionality, but also by its historical, scientific, symbolic and aesthetic interest, as inferred from the previous sections. It is the meeting of these values that allows us to understand the capacity of the bridge to transform the river into that point and turn it into a place, constructing a landscape that is more than the sum of nature and culture in the encounter of the estuary with the sea. It is the bridge that has gathered and related these spaces and gives meaning to the site as a place of passage.

## 3. THE DAMAGE OF THE BRIDGE. ANALYSIS, CHARACTERIZATION AND DIAGNOSIS

The results of the different inspections carried out in the framework of the bridge management system (SGP) developed by the General Directorate of Roads, the Ministry of Development<sup>10</sup>, highlighted the damage to the metal structure of the bridge. It was always decided to maintain the bridge paying for the damages through repairs, reinforcements and substitutions. For this reason, it has been important to document the repairs to which it has been subjected and, above all, to perform the analyzes that accurately show the type of wear, its scope and evolution over time.

### 3.1 INSPECTIONS UNTIL 1960

There are three documented reviews that showed signs of oxidation, a consequence of insufficient protection of metal surfaces. They were solved with chopping and scraping of the rusted parts and repainted with minium and metallic paint based

on silver glitter. The blocking of the mobile section, which had not been revolved since the first years of the postwar period, is also confirmed.

### 3.2 INSPECTIONS UNTIL 1965

It analyzed for the first time the conditions of resistance and stability and looked for a solution to reactivate the turn of the mobile section, although finally it was blocked. To know the resistant characteristics, a load test was carried out, and it was observed that in all the sections the deflection produced (3 mm in the mobile and 12.5 mm in the fixed ones) recovered completely, from which it was deduced that the stresses were in elastic period. A chemical analysis of the steel of the bridge determined that the material was easily weldable by any procedure, and thus all the unions intervened, of more than half, were repaired. The stiffness of the diagonals was also increased by welding them a metal sheet because they were considered to be very slender and, in addition, they produced a lot of noise when the vehicles passed, causing them to vibrate and clash. The broken vaults were reinforced by adding pieces of sheet metal. And the slab made of planks of the board was replaced by another one made of steel sheet, and the sidewalks also of wood by others of 8 mm fluted sheet with an asphalt layer. The drainage was also improved and the entire metal structure was painted. The trace of this intervention has been observed and valued in the current intervention.

### 3.3 INSPECTIONS FROM 1994 UNTIL NOW

Since 1994, several visual inspections have been carried out, contrasting the information obtained with the result of structural tests that measured the tensional responses to static and dynamic actions. For a precise knowledge of the damage, two types of analysis were carried out, a mechanical traction test to determine the modulus of elasticity, elastic limit, traction strength and breaking load, and a chemical analysis that sought to determine the carbon and sulfur content<sup>11</sup>. The study of the samples, from the

diagonals and metal plates of the two fixed sections of the bridge, concluded that the joint of the replaced elements with the old ones had to be done in the following way: welding with slow welding speed in the case of the diagonals, to avoid segregation in the old material; bolted joints in bracing lattices, to facilitate conservation; bolted joints in the reinforcement of the main beams, arches and upstrights to avoid spatial rigidity.

This analysis took into account relevant information obtained from another<sup>12</sup> conducted in 1996, which had allowed to know the type of iron used in the structure, which is important given the age of the bridge and the incomplete documentation preserved. The fundamental parts of the structural system of the Treto bridge, that is to say, the flat and angular plates and the "T" and "U" laminated outlines of the fastening framework, are made of wrought iron, generically called puddling iron in the European bibliography of the time, with an elastic limit estimated at 204 MPa. Therefore, it was recommended that the refurbishment techniques to be used would have to avoid spatial rigidities, that the joints had to be designed by screwing with friction work, and that in the case of making weld seams, it would be necessary to use coatings of small thickness that would contribute little heat energy. Likewise, the cutting techniques to be used should be mechanical (saw) or thermal (plasma, laser).

A third analysis<sup>13</sup> aimed to know the elastic capacity of the structure. For this purpose, an arc was instrumented through the placement of eight strain gauges for stress control, and the performance of the load-bearing elements (arc, tie beam, upstight) before and after the removal of 1617 cm of form and filling material was checked, resulting in an upward vertical displacement of 1 cm in the edge of the span, consistent with the theoretical model.

It was not considered necessary to carry out a tenacity test, which is mandatory in the studies for the improvement of materials, given the age of the bridge and the low variability foreseen for the actions to which it is subjected.

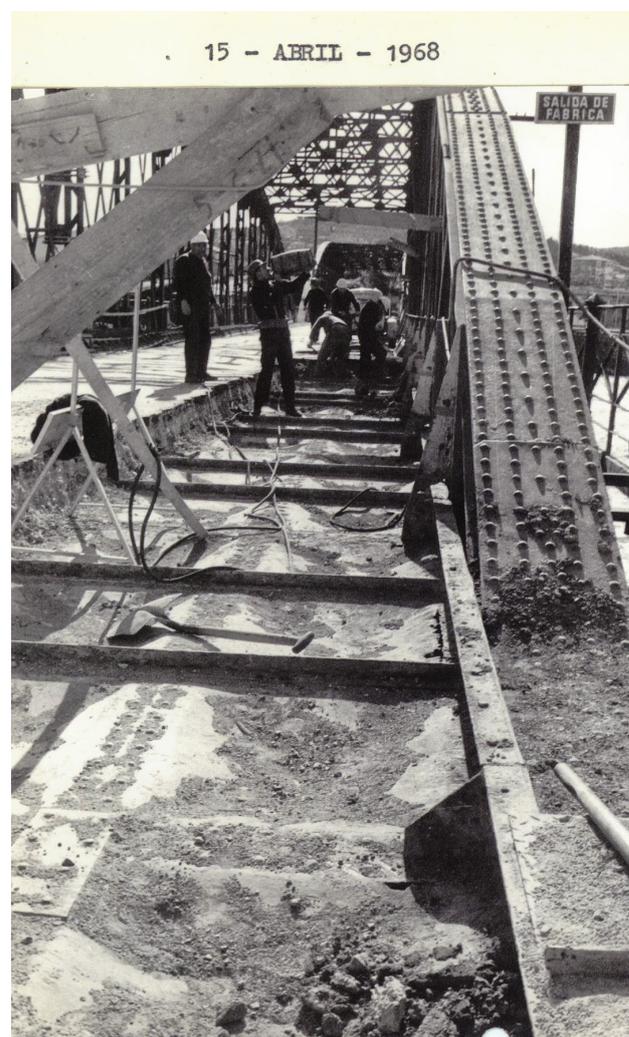


Figure 3.  
*The repair of the year 1968*

### 3.4 MOST IMPORTANT BRIDGE DAMAGE

The most relevant damages have been classified according to the resistant performance and functionality.

The damages caused by the resistant performance are:

- Corrosion, up to breaking, in numerous elements of the structure, highlighting the connections between upright and diagonals, between ties, between joists and main beams. It is a generalized damage caused by the deterioration and / or absence of surface protection, and serious because it endangers the safety of inaccessible pieces. At the meeting points of the elements,

water accumulates easily, which intensifies corrosion, deteriorating the rivets and gussets and decreasing the strength of the joint. The same and with similar consequences has happened in the metal sheets that make up the support slab of the padding of the platform.

- Instability of diagonals to compression strength
- The pavement and the curved and / or broken vaulted plates show the excess in the weight / bearing capacity ratio.
- Loss of section in the lower beam of the main beams
- Cantilever takeoff in the impost.
- Displacement of the walls in their joint with buttress.

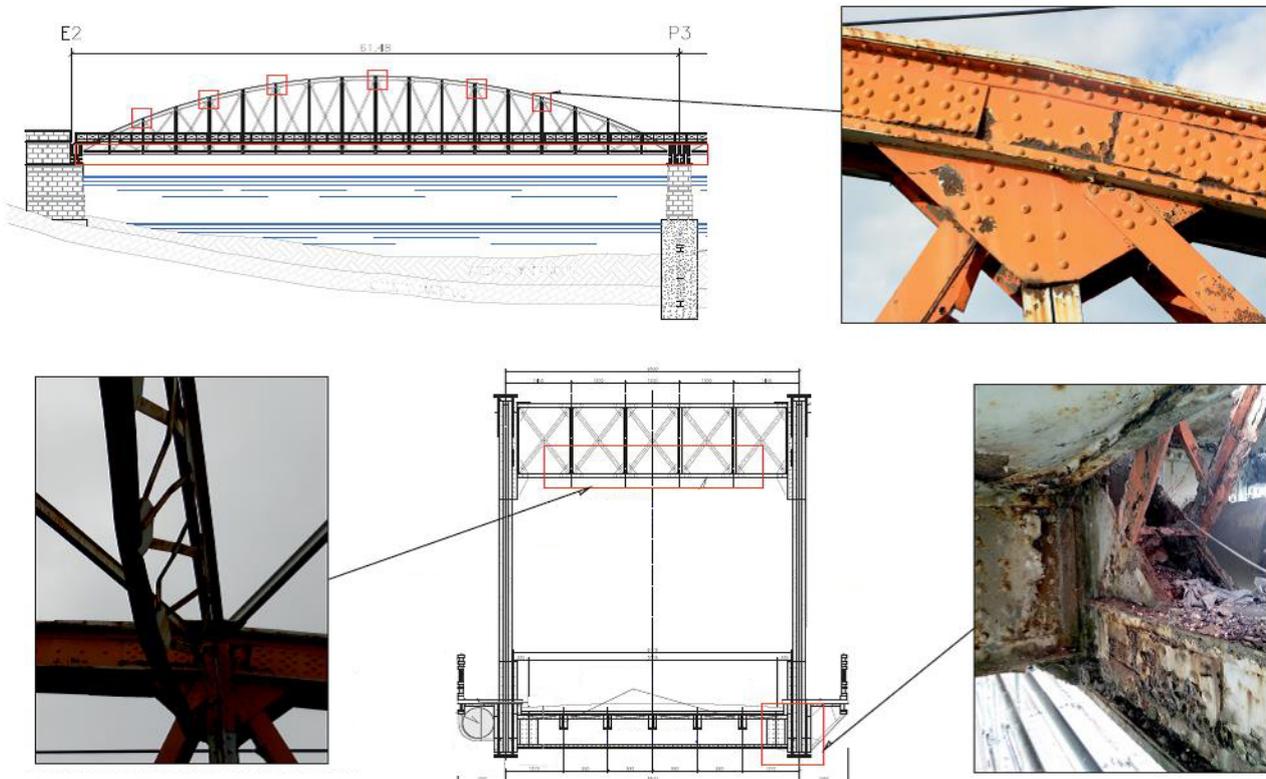


Figure 4.  
Corrosion in metallic elements. Situation of the arch.



Figure 5.  
*Deformations and breaks due to impacts*

- Cavities in the floor, under the buttress.
- The damage caused by the use of the bridge are:
- Deformations in diagonals and upstright caused by vehicle impacts. The typology of the bridge, the scarce horizontal gauge and the absence of protection elements explain the numerous collisions that have occurred, leading to the breakage of elements (brackets, diagonals).
  - Bulges and displacements in masonry parapets of buttress.
  - Breakage of parapets and slab
  - Leaks

The assessment of the damages described and their foreseeable evolution showed that the deterioration affected the structural safety of the bridge and its durability, as well as the performance of its function, so the recovery had to be undertaken with urgency. For being a bridge with a heterogeneous typology, it was decided to differentiate the intervention, by first refurbishing the two bow-string sections. The intervention in the mobile segment, which includes recovering the rotation mechanism, is being studied on this date.

## 4. THE REPAIR PROCESS AND THE REFURBISHMENT OF THE BRIDGE

The repair process was planned in several phases. The works were awarded to TECYR, Construcciones y Reparaciones S.A. The tasks detailed below were carried out.

### 4.1 PREPARATION OF THE WORK SPACE AND CLEANING

It was necessary to have a working platform under the bridge deck, which was made using modules of the Allround system by Layher. It was placed suspended from the deck by vertical tubes and anchored to it. It configured a scaffold that in addition to the suspended platform had four levels of modules placed on the outside of the arches.

To clean the surface oxide of all the metallic elements of the bridge, sandblasting was used. This treatment had to respect the current legislation in relation to the prohibition of dumping any product and / or material derived from cleaning the bridge into the riverbed.

For this, a scaffolding encapsulation system was designed, in sequential advance, consisting of an outer heat shrinkable plastic sheet that surrounds the scaffolding and a tarpaulin that wraps the upper face of the lower parts of the scaffolding, forming an enclosure to accumulate the waste generated in this cleaning operation<sup>14</sup>.

This system has revealed two advantageous evidences: one, that the material that forms the encapsulation allows to work in the interior with conditions of temperature and humidity adapted for the sandblast tasks and first primer, and another, that the control on the waste generated is optimal, both in its deposit and extraction.

#### 4.2 REPAIR OF METAL SURFACES

The refurbishment was organized according to three interrelated solutions: repair, reinforce and replace. All metal elements that make up the structure have been repaired by surface cleaning, consisting of washing and chipping to remove the oxide. The washing with water jet at 150 bars sought to eliminate the salt layer, whose surface deposit is due to the saline mist that is produced by evaporation in the estuary and which together with the water forms the accelerating



Figure 6.  
View of the encapsulated scaffold

electrolyte of the oxidation process. The subsequent mechanical chipping is done to eliminate residual chipping.

Afterwards, a dry abrasive blast was carried out with silica sand (No. 12 ASTM sieve) up to grade Sa2½ (almost white metal) and roughness profile Rz45 / 75. The Elcometer 138 kit was used to measure the surface soluble salts after trickling. Then a 50µ Sigmacover 280 of primer coat was applied, consisting of a pure epoxy anticorrosive system, whose main advantage is that the overcoating interval, 3 months, allows repair before proceeding to the second layer.

After the removal of the material and the encapsulation, a new visual inspection made it possible to evaluate the remaining thickness of the steel and calculate the reinforcements needed to restore the resistant sections, both of the fixed and mobile sections. Packs of sheets capable of transmitting loads were formed, replacing the section of steel lost by corrosion. In order to form these packets, it was necessary to remove pre-existing sheets that prevented access to untreated layers, and to clean and treat them before placing the new ones. The sanitization consisted of a superficial cleaning by mechanical means and the application of Sigmafast 20 which is a primer based on alkyd resins modified with zinc phosphate. The new sheets, after being treated with blast and Sigmacover 280 primer, were put into operation.

Thus, all the lower knots of the transverse-tie and lower-upstright were reinforced in the fixed sections of the arches, as well as 32 upper knots in the upper-tie upstright connection. In the diagonals of the arches, all the unnecessary link lattices were removed, placed in previous repairs, getting back the transparency that it had in its original form. All upper bracing lattices between arches and 16 vertical struts have been replaced. In the case of the mobile section, the longitudinal beams and transverse beams have been reinforced.

It has been verified the good functioning of the posts, which have not been replaced except those hit or those that have lost a lot of section. The lower part of them, usually deteriorated, has been reinforced by providing two "U" profiles in the anchoring areas of the transverse stringer.

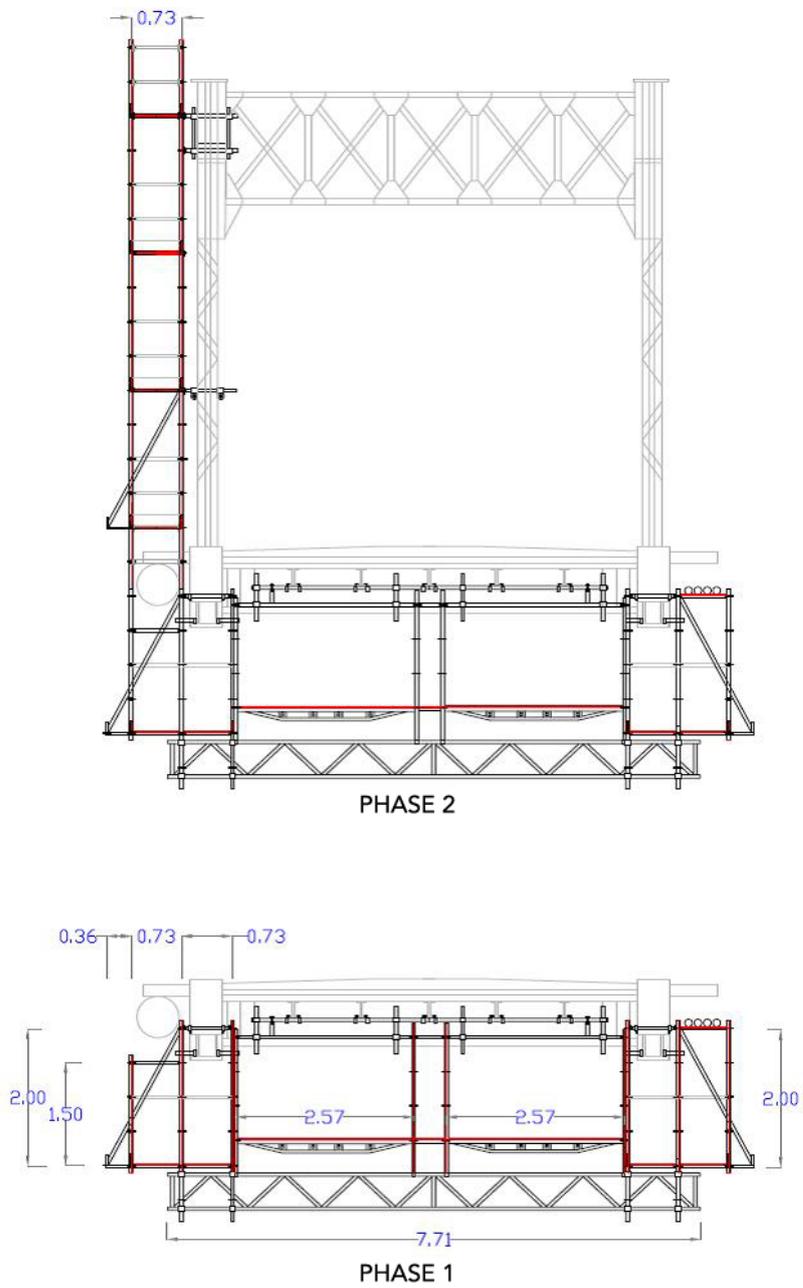


Figure 7.  
Modular scaffold Allround System by Layher

All the metallic elements have been joined to existing ones by means of high strength screws, as well as lost, broken or loose rivets. In total, 22,000 rivets have been removed, replaced by as many screws, longer (Standard 14399-4) because repairing the thickness of the sheet packs is increased.

#### 4.3 REPAIR OF THE DECK

The actions on the platform began with the elimination (up to 44 cm thick) of the existing agglomerate on the metallic vaults (8 mm thick sheet) that make up the framework between transverse and longitudinal beams of the deck, which constitute a typological

singularity of this bridge. After the milling of the entire layer of the firm, the slab of the fixed sections of the bridge was analyzed. Based on the results of the structural analysis, a reinforced concrete slab (HA30 / B / 20 / IIIa) with nominal top face coating of 35 mm and a crack opening limit of 0.2 mm was executed. The slab is placed concreted on the original vaults and works without connection to the metallic structure except for the head of the transverse beams to which it is connected by two rows of connectors.

The operation is correct<sup>15</sup> both for the metal structure

**Figure 8.**

*Angular reinforcement process: 1. removal, 2. installation, 3. welding, 4. strengthening parts*



and for the slab, with all the elements in the range of the resistive and tensional limits. There is an exception in the union between the transverse beams and uprights, where the resistant capacity of the screws will force to lower the load of the vehicles (168 kN versus 200 kN of the Instruction), which will result in a restriction of passage for vehicles that exceed 50 t of weight. The cause of this diminished resistant capacity seems to be in a previous intervention not documented, that to slightly increase the horizontal clearance of the platform cut the union brackets.

**Figure 9.**

*Deck repair process: 1. 2. removal road surface, 3. 4. replacement and/or repair of small vaults*

A new waterproofing system ensures sufficient drainage capacity to the deck, with cleaning and unblocking of existing scuppers and construction of new ones. The internal filling of the main lower arc ties was replaced by a filling of expanded clay balls and sealing concrete, and the closing of the gap between upright, and also the expansion joints were replaced. A new vehicle containment system consisting of metal parapets has been arranged<sup>16</sup>. The original platforms were replaced by others of the same design but with greater overhang, going from 0.80 m to 1.90 m wide, supported by metal cross braces that allow to also house the conduits for services. This is the case of the water supply pipe, Ø600 mm, which has been placed under the sidewalk



on the upstream face. As protection to the step a railing has been forged whose lattice reproduces the design of the original.

#### 4.4 PROTECTIVE TREATMENT OF THE METAL STRUCTURE

The entire surface of the sanitized metal structure has been protected with a coating system resistant to the marine environment, with thickness between  $280\mu$  and  $400\mu$ , which involves the following steps: sealing of the joints capable of retaining water by means of a sealing bead and a thixotropic adhesive, a component based on polyurethane, of permanent elasticity and fast curing (Sikaflex 11FC); to improve the appearance of the surfaces, thicknesses are recovered with a special putty formed by a thixotropic structural adhesive, bicomponent based on epoxy resins without solvents and selected fillers (Betopox 920P Propamsa); degreasing with application of a solvent and cleaning with absorbent rags of the residual cutting oil and burned areas; mechanical and manual brushing of the welds, returning to sandblast the rusted areas and repainting; To eliminate the

waste generated by the repair, another surface washing was carried out with water under pressure, and drying by blowing.

The application of the paint has differentiated the areas below and above the deck, according to EN ISO 12944-5 which in addition to requiring a high life expectancy, considers the part on the industrial category deck and part under marine category deck. In the former (C5-M, life expectancy > 15 years), a high-thickness polyamine adduct epoxy two-component coating between  $150\mu$  and  $200\mu$  (Sigmashield 880) was used; and in the second (C5I, life expectancy > 15 years) two coats of epoxy primer of  $70\mu$  (without solvent cured with polyamine, Sigmacover 1500) and  $60\mu$  (with zinc phosphate of two components and high solids, fast curing and recointable low temperature, Sigmafast 278); and two other layers of  $50\mu$  each of acrylic aliphatic polyurethane (Sigmadur 550). This system of painting has been chosen to temper corrosion as effectively as possible, given the evidence that this deterioration process has been the main cause of the poor condition of the bridge.



Figure 10.  
Current status of the refurbished stretches

## 5. CONCLUSIONS

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This text describes the damage that the Treto bridge presented, a metal passage structure inaugurated in 1905, and the tasks performed to restore functionality according to current requirements, which was the main objective of the action. Special emphasis has been placed on the treatment of surfaces after structural repair, due to the importance it has for the conservation of the bridge.

The corrosion of the metallic elements that make up the structure is the main diagnosis for the problems of the bridge. It is an irremediable process, accentuated by the marine environment in which it is located and also by the poor protection of surfaces and / or aging. For this reason, it has been important to protect with an effective and adequate paint treatment, and to observe its evolution.

The bridge is not included in any of the legal regimes for the protection of the cultural heritage of Cantabria<sup>17</sup>, but this does not diminish its value. They are known reticence of cultural administration to engage with living works that must maintain their functionality ensuring compliance with current safety standards and prefer not to enter into controversy with other public bodies (hydrographic confederations services regional and national routes toward, for example).

But its value is real and includes both historical and aesthetic, structural and landscape aspects. For this reason, the intervention sought to reduce the impact between the existing and the new, both in the bridge and in the environment, with the aim of minimizing alterations in the nature of the place.

During the works, the bridge has frequently been the object of attention by the press, interested in the scope of the work and in meeting deadlines. The involvement of the media in the monitoring of refurbishment can also be understood as a way of contributing to the enhancement of the cultural heritage of public works, not in vain only what is known can be appreciated.

## NOTES

1 The examples refer to bridges of three sections, all fixed. There are numerous bow-string beams bridges built in Spain (and around the world). On the bridge of Coria you can consult <https://lascarreterasdeextremadura.blogspot.com/2012/03/rehabilitacion-del-puente-metalicode.html>. The repair projects and files of this bridge in Extremadura, and Villafer (León) and Toro (Zamora) are accessible through the Road Infrastructure Service of the Ministry of Economy and Infrastructure of the Junta de Extremadura, and the Road Service and Transport of the Ministry of Development and Environment of the Junta de Castilla y León.

2 On the patrimonial consideration of public works and their evolution from the field of civil engineering, it is possible read the texts of the monographic issue of the Journal of Public Works (2014, 161 (3559)).

3 The origin of technical documentation of a historical nature is scattered, and the main funds are located in the General Archive of the Administration (AGA), Archive of the Ministry of Development, National Historical Archive, File of the Demarcation of State Roads in Cantabria, File of Factory of Mieres (Gijón) and Municipal File of Mieres, that are the institutions in charge of their guard and custody.

4 The environmental conditions for the work can be read in the Cantabria Law 2/2004, of September 27, of the National Plan for the Management of the Coast of Cantabria. BOC 28/09/04, N°21 and Law 4/2006, of May 19, of Conservation of Nature of Cantabria. BOE 03/08/06, N°184.

5 An interesting contemporary story that narrates this conflict that can be read in *La contra al proyecto de el puente en Treto, o defensa de la navegación hasta Limpías*, article published in 1885 in the newspaper *El Cántabro*.

6 Local historians A. Setién and A. Revuelta have collected documentation explaining the political game that developed during the Restoration dynastic parties using the work of the bridge in terms of the interests of clientelism.

7 About manufacturing technology can be read the interesting chronicle of the Mieres Factory between 1879 and 1967 published by the company itself, which also has its own documentary collection kept in the Municipal Archive of Mieres (Asturias).

8 Regarding the controversy can read the text of Pablo Alzola (Bilbao, 1892) about industrial art in Spain. In NAVARRO VERA (2001) there is a more detailed explanation.

9 The project dated in 2016 (Cimiano and Pantaleón) serves as the common thread for all the documented conservation tasks.

10 The Directorate General of Roads of the Ministry of Development published in 2012 (Madrid, Publications Center of the Ministry of Development) a guide for carrying out main inspections of road works in the State Roads Network, which is the one that has been followed.

11 The chemical and mechanical analyzes of Treto bridge were carried out in 2015 by the company APIA XXI

12 The company SGS carried out in Madrid in 1996 first mechanical and chemical analyzes of samples of materials from the fixed section.

13 The company APIA XXI carried out since 2015 a follow-up of the data coming from the instrumentation: initial milling process in span 3 of the bridge.

14 The cleaning operation must comply with the provisions of Royal Decree 105/2008, on February 1st, which regulates the production and management of construction and demolition waste. BOE 02/13/2008.

15 As established by the General Directorate of Roads of the Ministry of Development in its Instruction on the actions to be considered in the road bridge project, published in 1998 (Madrid: Publications Center of the Ministry of Development).

16 These metal parapets comply with Circular Order 35/2014, in May 19, 2014, on criteria for the application of vehicle restraint systems.

17 Law 11/1998, in October 13, on Cultural Heritage of Cantabria. BOCT 2/12/1998, N°240 Consolidated text in 12/30/2013 From <http://www.culturadecantabria.com/listadopatrimonio> It is possible to access to the classification and assets.

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## REFERENCES

- Aguiló, M. (2013). *Qué significa construir. Claves conceptuales de la ingeniería civil*. Abada Editores. Madrid
- Ballester, J. M. (2014). Evolución del concepto de patrimonio cultural en Europa: la incorporación de las obras públicas. *Revista de Obras Públicas*. 3559, 7-12
- Cimiano, F. y Pantaleón, M. (2016). Proyecto de rehabilitación del puente metálico de 1901. Carretera N-634. PK 170,300 al PK 170,485. Tramo: Puente de Treto. Santander
- Crespo Delgado, D. (2017). *Preservar los puentes. Historia de la conservación patrimonial de la ingeniería civil en España (Siglo XVI - 1936)*. Fundación Juanelo Turriano. Madrid
- Díez - Luis, L. (1873). Carreteras de la provincia de Santander. *Revista de Obras Públicas*, I(1): 7-11
- Fernández - Ordóñez, J. A. (1995). Obras públicas y monumentos. *Revista de Obras Públicas*, 3347: 7-13
- Fernández Troyano, L. (1999). *Tierra sobre agua. Visión histórica universal de los puentes*. Colegio de Ingenieros de Caminos, Canales y Puertos. Madrid
- Mendizábal, D. (1928). *Estudio y construcción de tramos metálicos*. Sucesores de Ribadeneyra, Madrid
- Molinos, R. y Pronnier, C. (1857). *Traité theorique et pratique de la construction des ponts metalliques*. Lacroix et Baudry, Paris
- Nárdiz Ortiz, C. (2007). Obras de ingeniería y creación de paisajes. *Revista de Obras Públicas* 3474, 19-32
- Navarro Vera, J. R. (2001). *El puente moderno en España, 1850-1950. La cultura técnica y estética de los ingenieros*. Fundación Juanelo Turriano. Madrid
- Ruiz - Bedía, M. (2009). Estudio de las características estructurales exteriores del puente de Treto, N-634, previo a la ejecución del Proyecto de Clave 38-S-3600 de rehabilitación del puente metálico de 1901. Santander: Universidad de Cantabria
- Setién, A. y Revuelta, A. (2005). *A través del puente*. Colindres: Excmo. Ayuntamiento de Colindres