Rehabilitation of the Minho line's Areosa and Afife masonry railway bridges

Fernando Martins
REFER EP – Bridge Conservation and Repair, Portugal

ABSTRACT: The Areosa and Afife Bridges, sited respectively at PKsº 85.619 and 91.487 of the Minho Line, are two of that Line's most beautiful and emblematic Bridges of this kind. Built in 1890, they are two masonry structures made of stone elements, forming an abated arch vault with an approximate span of 14 and 12 metres respectively.

Due to the problems they presented, railway traffic was carried out with speed restrictions. REFER then considered to carry out some rehabilitation work in order to re-establish in that Line the normal traffic conditions. With this purpose, it opted to reinforce the bridges with trussed beams and pegs placed transversally to the railway line, being foreseen the consolidation of the respective strongbox in both structures.

1 INTRODUCTION

The Areosa and Afife Bridges, with total lengths of 21.60 and 16.90 metres respectively, are part of a straight single line stretch, with traffic speeds of 100 and 140 Km/h, made of twin block concrete sleepers set on a layer of ballast of about 10 centimetres.

Figure 1: Areosa Bridge

Figure 2: Afife Bridge

Both structures showed evident signs of degradation with cracks in all of the intrados of the vault, standing out two greater sized cracks that followed the structure in a longitudinal direction causing the detachment of the frames. Even thus, the masonry elements of those lateral faces were perfectly levelled between themselves. In the Areosa Bridge, the one showing greater damage, a slight subsiding of the inside of the vault could be seen, with some individually displaced stones.

The gradual subsiding of the inside of the vault was a consequence of the detachment of the frames, in its place caused by the dragging of fine coating material from the interior of the strongbox outwards.

Figure 3: Areosa Bridge – Frame detachment

Figure 4: Detail of the crack

These abnormalities derived not only from the antiquity of the structures and the action of rain water over the years, which progressively degraded the masonry joints, but also from the low height of the existing ballast, which led to a greater dynamic aggression on the part of the passing rolling stock.

In this way, considering the observed degraded state of both Bridges, and in order to stop the existing restraints that were harming normal railway traffic, the rehabilitation of both structures was carried out.

Before such rehabilitation was executed, it was carried out the substitution of the concrete beams by wooden ones, and also the heightening of the levelling in those stretches of line. This smoothed the dynamic impact of train circulation by distributing the weight over the structures in a more uniform way.

2 STRUCTURAL SOLUTION – INTERVENTION PLAN

Of all received proposals the S.T.A.P., Reparação, Construção e Modificação de Estruturas (Repair, Construction and Structure Modification) SA company was selected, which accompanied by the Engineering and Services Cabinet. Their solution foresaw the use of trussed beams and pegs placed transversally to the railway line, to be later sealed with a cement solution.

The project developed for the improvement of the Areosa Bridge consisted basically of globally increasing the stability of the elements that compose it, namely the masonry structure of resistant stone, on its transversal plane.

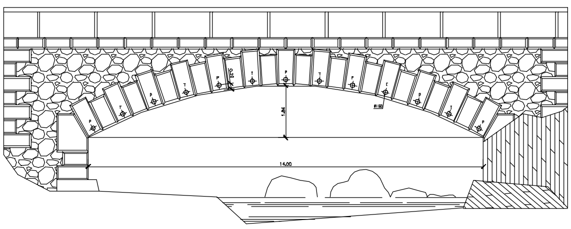

Figure 5: Solution type – Trussed beams and pegs

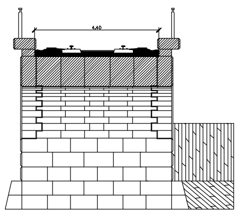

Figure 6: Transversal plane

As the whole structure of the Bridge was not affected, it was decided to endow the structure with a greater transversal resistance capacity in order to grant an overall response in case of possible soil displacements or the transversal deformation of the stone arch.

At the Afife Bridge, the rehabilitation process was practically identical to that carried out with the Areosa Bridge, though without the application of beams and pegs, as it did not show problems of the same degree of seriousness. Thus, the improvement consisted basely in bettering its structural behaviour by filling up and closing the existing cracks with cement solution.

3 PROJECT

The goal at Areosa Bridge was not to return to its original geometry, but only to make it stable. In this way, the chosen solution did not derive from a strict mathematical model, as it was only intended to re-endow the Bridge with its original characteristics in order to stop the transversal deformation, i. e. stop the desegregation of the stone blocks making up the frame on both sides in relation to the inside of the vault.

Thus, the stopping mechanisms consisted in the placement of trussed beams, alternately applied with 1.5 meter long pegs (latches) being placed in the greater sized stones, totalling 6 beams and 7 pegs on each side of the Bridge.

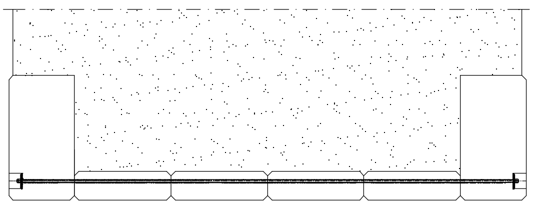

Figure 7: Trussed beams

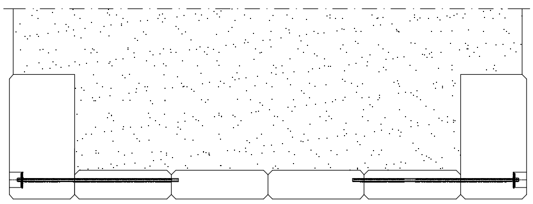

Figure 8: Pegs

The application of the latches worked as a complement to the beams which had the goal of establishing a proper connection between the lateral faces of the Bridge and the rest of the structure, acting in a cutting and traction way, thus stopping any relative movements.

The rods used on the beams and pegs were made of A400 NR steel, with a diameter of 25 millimetres, threaded at M20 at the tops and endowed with both a nut and a lock-nut. In the anchorage and distribution plates S235 JR steel was used with Ø 150 x 10 mm, which were set over cushions of retraction-free mortar. All these metallic elements were subjected to an anti-corrosion protection treatment that included mechanic scouring at the degree of AS two and a half, and the application of a coating of zinc dust rich primary epoxy – 100 microns.

No tension was applied to the beams other than that resulting from their adjustment for the elimination of deformation due to the flexion caused by the own weight of the rod. For this purpose a tightening force was applied via a dinamometric wrench.

This solution pointed to the soaking of the anchorage plates, formed in “boxes” that were later sealed for esthetical reasons.

4 EXECUTION

Work began with the cleaning and repair of all masonry joints. Those that showed degradation or looseness were properly pricked, washed and blown with the care needed not to damage the stone. In the same way, those that had been colonised by grass, algae or lichens, were given a biocidal product, being their removal carried out with the least possible damage to the masonry. The mortar that was strongly connected and consolidated to the stones was left untouched, as it was “healthy”. In general, the joints were exposed to a depth of about twice their width.

Figure 9: Areosa Bridge – Cleaning

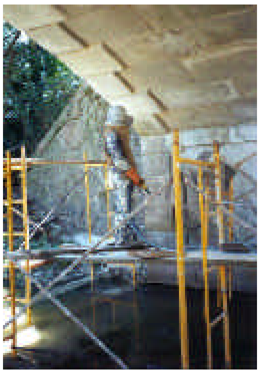

Figure 10: Afife Bridge Cleaning

At the same time, at Areosa Bridge, holes were made for placing the beams and pegs via the use of rotating cutting material. As they were being finished, the rods and the anchorage plates were put in, and both nuts and lock-nuts were tightened. In all anchorage plates an opening was left for a tube to be placed through which the cement solution was later injected.

Figure 11: Masonry perforation

Figure 12: Perforation equipment

Figure 13: Anchorage plates

Once the cleaning had been done, the joints were re-closed with mortar with a colour matching that of the existing stone. This process was carried out from the bottom to the top in vertical strips, being fully carried out at the first attempt. After this, the mortar surplus was cut off and the wall washed. The mortar was placed over the expectant material, which was put against the wall, immediately under the joint. With a mason’s spoon the mortar was applied on the joint which was later creased with an iron hook in order to make it compact. The joints were dampened by pulverisation 24 hours before they were closed, in order to control the absorpsion of water by the mortar, thus avoiding early cracking and loss of adhesion and resistance. The operation of re-closure was only carried out after the air temperature had reached between 5º and 20º C.

The new mortar was protected from the direct contact of rain, wind and sunshine by an adequate covering coating and was also kept slightly damp in the first few days in order to prevent cracking, especially in hot and dry weather.

After the accomplishment of the re-closure of the masonry joints with mortar, so as to allow them to function with an impervious lateral curtain, the injection of the cement solution was started in order to fill up empty spaces and to consolidate the filling material of the Bridge’s strongboxes.

This injection was carried out, whenever possible, from the bottom to the top, at low pressure, from previously executed holes that crossed the covering stones. These rigorously made holes were made with a mallet and small beams following a network set in staggered on both sides of the Bridge and also on the inside of the vault 1” tubes were left in these holes that served for both the injection of the solutions and for purges made to verify their level of progression. In this way, the advancement of the solution in height could be controlled, making sure that the area would be perfectly filled up and thus consolidated.

Figures 14, 15, 16, 17 and 18: Injection of the Bridge’s strongboxes

This operation was carried out simultaneously with the injection of the be60ams and pegs and finished after all tubes had been conveniently sealed.

Figures 19, 20, 21 and 22: Injection of the beams and pegs

The solution was made with a product consisting of special cement and additives, of great fluidity, easiness of pumping, lacking retraction or exudation and of adequate mechanic resistance to the surrounding masonry. It was prepared with appropriate equipment, with an initial induction of 80 % of the total amount of water required, followed by the application of the cement-based product in a quick and continuous way until a plastic and homogeneous mixture was obtained. Later, the remaining 20 % of water were added.

In the injection operations manual equipment was adopted which allowed pressure to be controlled. Through this screening, it was assured that it did not exceed the pressure that the superficial sealing could support, nor that levels that might damage the injected elements or the rest of the structure were attained.

Water leaks in the canals that washed the mortar at the masonry joints were dealt with by resorting to injections of a solution of hidroactive poliuretan resin.

Finally, after verifying that the nuts were properly screwed, all injection tubes were removed and the plugging of negatives was carried out. These had been previously opened to make the beams and pegs using the same stone mould which was meanwhile reused and disguised with mortar so as to try to “imitate” the texture of the stone.

Figure 23 and 24: Areosa and Afife Bridges – Final look

To end, it should be said that the completion of the work was carried out without ever having to cut off the Line’s traffic, being the rolling stock only subjected to a permanent slowing down of 20 Km/h.