EXPERIENCES ON REPAIRING, STRENGTHENING & WIDENING OLD ARCH BRIDGES

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SUMMARY

A large number of existing old arch bridges need to be rehabilitated or widened due to the increased transportation and/or loading requirements that have arisen since their original entry into service. This paper presents a couple of existing arch bridges in Spain that have been rehabilitated and gotten widened. Its design are an illustrative example of the huge possibilities available to structural analysis, advanced methods of execution and the use of new materials in repair projects on existing bridges.

Keywords: *Analysis, reliability, rehabilitation, strengthening, widening, bridges, masonry, culture.*

1. INTRODUCTION

The rehabilitation of old bridges gives the structural engineer the opportunity to pose imaginative technical solutions in which the knowledge of advanced methods of structural analysis and the evaluation of structural safety levels using reliability techniques become elements of enormous value during the study phase of alternatives and for the final determination of the structural elements to be used. A construction system that combines structural elements both built in site and prefabricated has brought about a reduction in overall construction time and of the reduction of the impact that the work itself wreaks upon the riverbed by considerably reducing the auxiliary means of construction, as well as achieving a higher level of quality in the finished work. We present a couple of cases of bridge rehabilitation and widening.

The first one, a expansion design project for a historical masonry bridge over the Llobregat River on the BP-1121 road in the town of Monistrol de Montserrat, Barcelona, Spain, is presented The structure consists of four masonry arches of different lengths and a before-construction upper deck 7.95m wide.

A detailed previous prospection and geotechnical campaign showed that both the earth underneath the slab deck and the slab deck itself are in sound condition. Conversely, the cantilevers backing the sidewalks were not in such good condition. Not only the concrete was in very bad condition, but also it turned out that there were no reinforcing steel whatsoever.

Taking in account all of that, the design consisted of baking a new slab deck on the existing one, getting rid of the cantilevers by sawing them off of the bridge. The solution for the new slab deck consisted of 75 precast concrete pieces combined with an in situ slab deck. Road connections were arranged accurately on both bridge sides to improve both traffic and pedestrians flows. The construction also included a proper walkway and safety parapets along the bridge. Lastly, a detailed and extended rehabilitation work was carried out including cleaning with high pressured jet of water on masonry surfaces and sand blasting on concrete surfaces, crack injection, surface regeneration, restore of missing masonry pieces, filling of joint masonry, earth stabilization and surface protection.

Secondly, we present the widening of an existing masonry bridge on the C-1415c local road over the Argentona River, connecting the town of Argentona and the C-60 highway in Barcelona, Catalonia, Spain. It is a 10m five-span masonry arch, with an upper deck 0.43m thick and 9.50 m wide with both 1.75m wide cantilevers. The cantilevers stretch in 1.85m, living a 2.8m wide central filled with earth, not with structural concrete.

The main issues were the discontinuity in the existing slab deck, non-suited safety barrier along other minor deficiencies, such as clogging in the drainage system and concrete loss.

A safety barrier was installed to meet the requirements of the EN-1317 code. Due its dimension, it was necessary to widen the bridge to accommodate them along convenient sidewalks. A proper bridge prospection carried out before construction showed a 2.8m wide longitudinal discontinuity between the bridge central part and its two side cantilevers. Therefore, the slab deck calculations do not comply with the overturning equilibrium limit under the least favourable loading hypothesis in accordance the EHE Spanish bridge code. A prestressing system was design in order to give the slab deck the necessary stabilizing force.

2. WIDENNING, REHABILITATION AND REFURBISHING OF A MASONRY BRIDGE ON BP-1121 ROAD IN MONISTROL DE MONTSERRAT (BARCELONA)

We present the expansion design & build project for a historical masonry bridge over the Llobregat River on the BP-1121 road in the highly visited town of Monistrol de Montserrat, Barcelona, Spain. The bridge was originally built during the 13th century and was partly blown up in the Spanish Civil War in 1939. The structure consists of four masonry arches of different lengths, 28.34 m, 23.11 m, 33.89 m, and 54.0 m (Fig. 1), and an original upper deck 7.95m wide.

Site inspection of the existing historical bridge, special inspection and preliminary reports of existing damage, identification and cause of cracks and fissures, core-sample extraction and material testing (Fig. 2), bridge load rating analysis, rehabilitation procedure approach, methods of construction, structural report of the new widening structure, were carried out before construction.

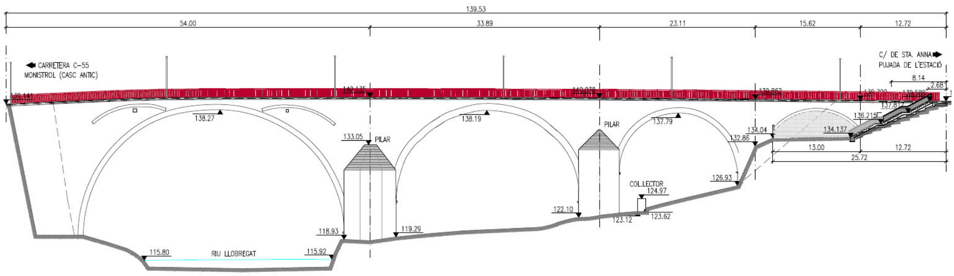

Fig. 1. *Bridge elevation.*

Fig. 2. *Special inspection and prospection and geotechnical campaign.*

As a result of a detailed and extend design project, a combined precast and in situ slab deck was built over the original slab deck, due to the extremely good condition of both the earth and the slab deck. It has been a gain of 3.37m in wideness, from 7.95m (Fig. 3) to 11.32m after-construction (Fig. 4).

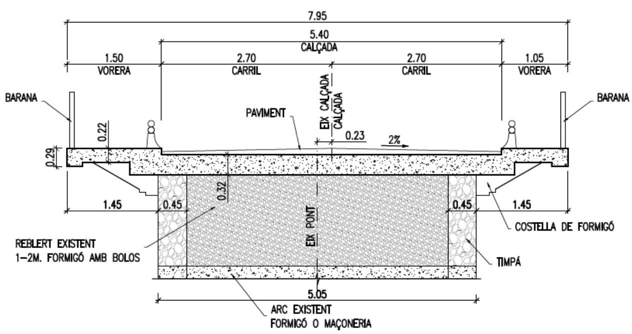

Fig. 3. *Original cross section.*

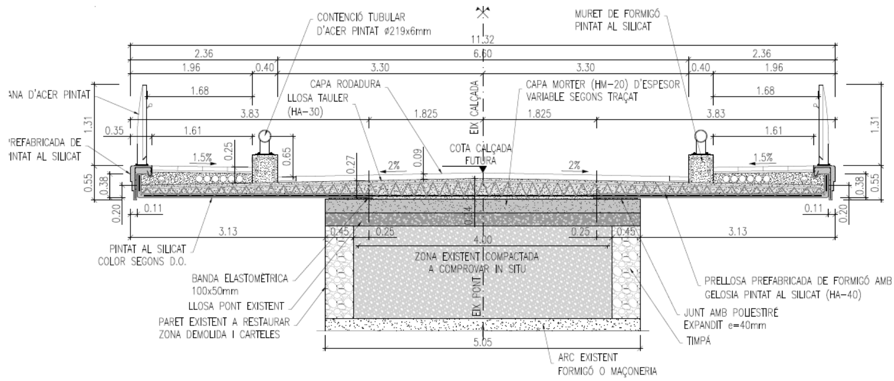

Fig. 4. *After-construction cross section.*

The existing road surface was demolish before a detailed topographical survey to establish the geometry of the new bridge (plan and elevation). Two longitudinal concrete bases were built over the existing slab deck so as to ensure the precise elevation on every section of the new bridge (Fig. 5).

Due to the particular features to the town, it was required to allow pedestrian flow anytime at daytime. Vehicular traffic was to take a 9km deviation route that did not take up more than 10 minutes. That is why deconstruction and new deck construction works had to be done at night time.

Fig. 5. *Longitudinal base and neoprene bearing for the new precast slab deck.*

Both the deconstruction of the existing cantilevers and the construction of the new slab deck were at night time in just 10 nights with a construction ratio of 15m per night. The construction system consisted of sawing the cantilevers off of the bridge (Fig. 6) right before putting the precast slab deck on place by means of a 130Tn crane (Fig. 7)

Fig. 6. *Saw used to dismantle both cantilevers off of the main existing slab deck.*

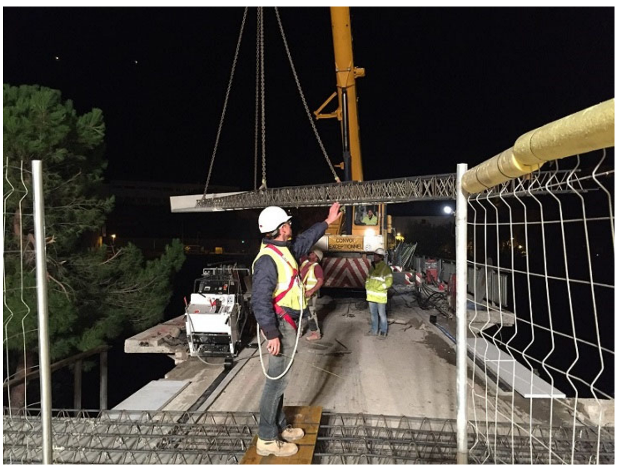

Fig. 7. *Precast slab deck craned on to place.*

The pouring of concrete on the central part of the slab deck was the tenth night once all of the reinforcing steel was put in place (Fig. 8). A week after, once the concrete reached the necessary strength, concrete was poured down in the cantilevers.

Fig. 8. *Concrete pouring. In situ slab deck.*

Once structural works finished, road and sidewalk works followed up (public utilities, sidewalk concrete, pavement, handrail, safety barrier, lightning, slab deck isolation, drainage, road surfacing, etc. – Fig. 9).

Fig. 9. *Sidewalk and road works.*

The rehabilitation project preserves the existing historic arch, masonry walls and exterior wall supports. Several elements of the existing masonry-bridge were repaired, such as the arches, the spandrel walls, the abutments and the wing walls. The main works completed were cleaning with high pressured jet of water on masonry surfaces and sand blasting on concrete surfaces, crack injection, surface regeneration, restore of missing masonry pieces, filling of joint masonry, earth stabilization and surface protection. Special means of elevation were required to gain access to some parts of the bridge (Fig. 10 and 11).

Fig. 10. *Rehabilitation works.*

Fig. 11. *Rehabilitation works.*

3. WIDENNING, REFURBISHING AND STREGHTENING OF A MASONRY BRIDGE ON THE C-1415C ROAD IN ARGENTONA (BARCELONA)

We present the widening of a 11 m five-span masonry arch bridge (Fig. 12) on the C-1415c local road over the Argentona River, connecting the town of Argentona and the C-60 highway in Barcelona, Catalonia, Spain.

Its upper deck is 0.43 m thick and 9.50 m wide with both 1.75 m wide cantilevers. The cantilevers stretch in 1.85 m, living a 2.8 m wide central filled with earth, not with structural concrete (Fig. 13).

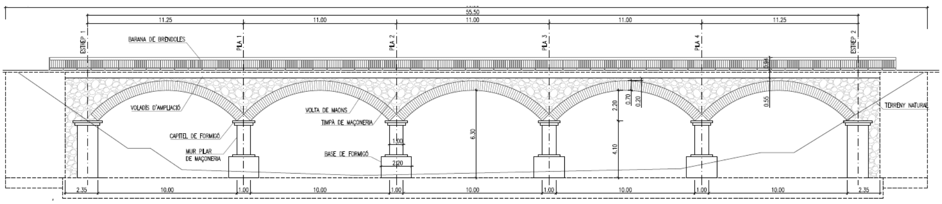

Fig. 12. *Bridge Elevation.*

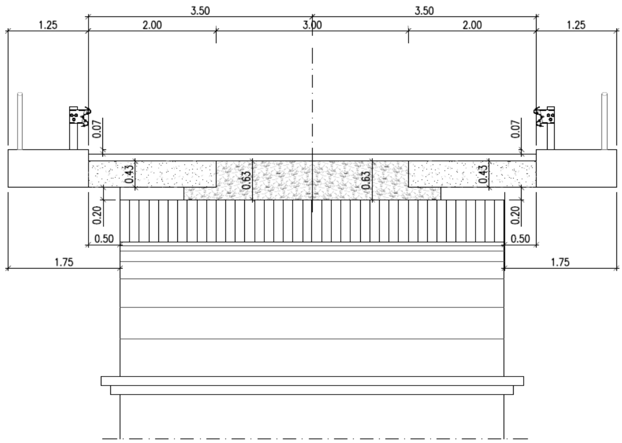

Fig. 13. *Typical bridge cross section.*

As we already stated in the introduction, the main issues were the discontinuity in the existing slab deck, a non-suited safety barrier, along other minor deficiencies, such as clogging in the drainage system and concrete loss.

A safety barrier was installed to meet the requirements of the EN-1317 code. Due its dimension, it was necessary to widen the bridge to accommodate them along convenient sidewalks (Fig. 14 and 15)

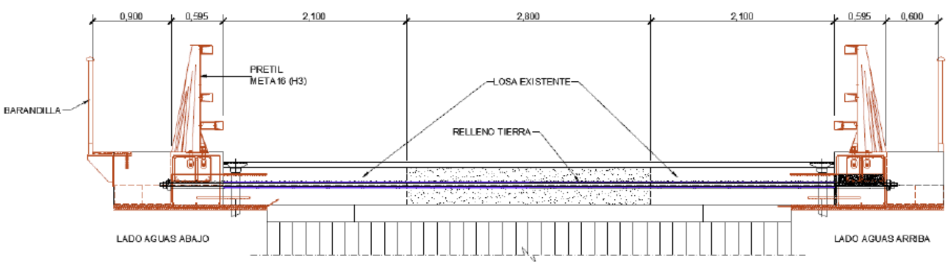

Fig. 14. *New bridge cross section.*

It was necessary to build a longitudinal member under the safety barrier to have it properly anchored and to ensure a proper transmission from the effects of the action to the slab deck (Fig. 15).

Therefore the effects of the forces originated in the barrier in case of an impact go totally to the upper deck and are not significantly transferred to the existing cantilevers (Fig. 15).

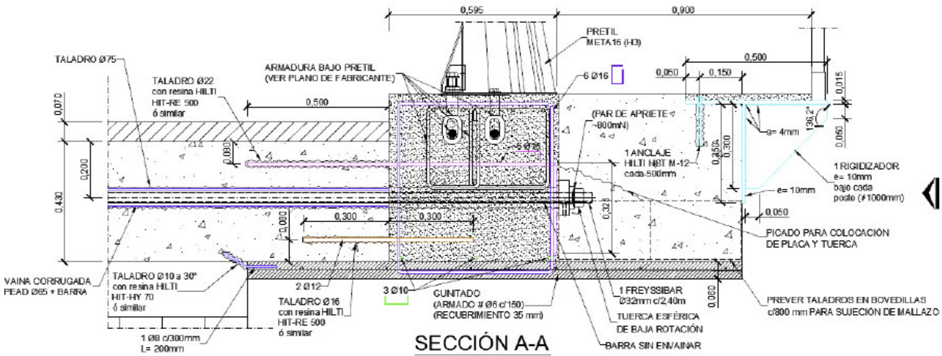

Fig. 15. *Detailed drawing for the sidewalk and new safety barrier expansion.*

In order to make the slab deck calculations comply with the overturning equilibrium limit under the least favorable loading hypothesis in accordance the EHE Spanish bridge code, a prestressing system was design in order to give the slab deck the necessary stabilizing force.

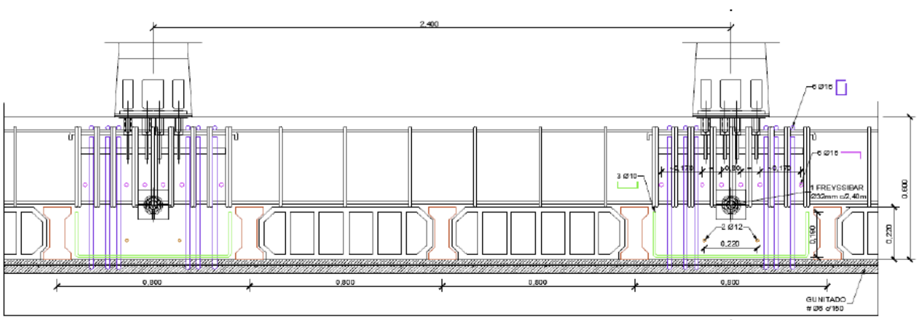

Fig. 16. *Frontal cross section.*

The construction works were completed in less than a couple of months and no significant traffic problems were reported (Fig 17).

Fig. 17. *Safety barrier installation.*