REFURBISHMENT OF CONCRETE ARCH BRIDGE IN NE ITALY

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SUMMARY

The bridge over Astico River is a 115 m long arch bridge, composed by 3 arch spans of 37 m, built at the beginning of the 20th century. Water infiltration was causing the deterioration and degradation of the first transversal beam in one of the spans. The steel rolling bearing were oxidated and not working. The intervention provided a new steel reinforcement to the transversal beam, coupled to the concrete element, and fixed at the lateral arches. The bridge was lifted in order to replace the old bearings with new ones. Particular attention was paid to the lifting operations, in order not to change the stress distribution of the bridge. Finally, a refurbishment was provided for the span, with the repair of the exposed rebars and the utilization of protective coat.

Keywords: *Concrete arch, steel reinforcement, lifting, refurbishment.*

1. INTRODUCTION

The bridge object of this paper is a r.c. arch bridge built in 1930 and firstly refurbished in 1984.

The bridge is located on the road SP121 at km 4+830, between the Municipalities of Breganze, Sarcedo and Fara Vicentino, in NE Italy.

The original bridge project was not available. The available information on the structure was obtained by visual surveys, geometric survey and in situ investigations on materials, as described below.

The bridge consists of three through arch spans (length of 36.65 m, 37.85 m, 36.65 m) connected to the deck with r.c. hangers. The piers and the abutments are 4 m high and are made of reinforced concrete with stone covering. The deck is constituted by a frame of longitudinal and transversal concrete beams. The transversal (primary) beams are directly supported by hangers while longitudinal (secondary) beams are supported by the transversal ones. The deck is completed with a r.c. slab and a asphalt layer.

The total length of the bridge is 111.15 m, developing a straight trail of the deck, with a width of 9.15 m. The road width has a width of 6.15 m and is divided into two lanes. Two sidewalks at the two sides of the road are present, with a width of 1 m.

Fig. 1. *Global picture of the bridge.*

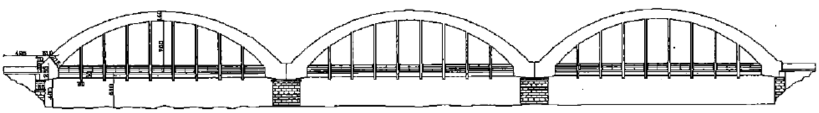

Fig. 2. *Lateral view of the bridge.*

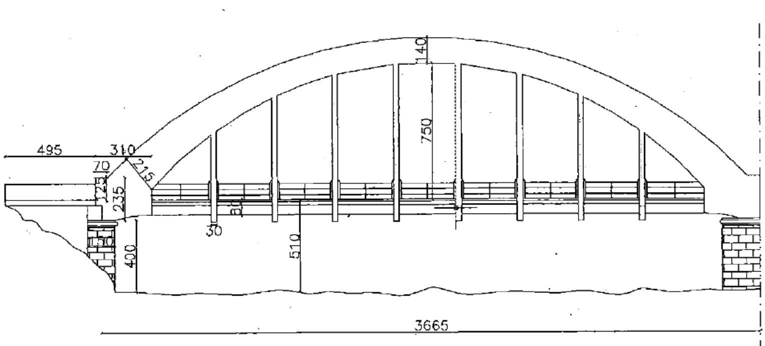

Fig. 3. *First span: lateral view.*

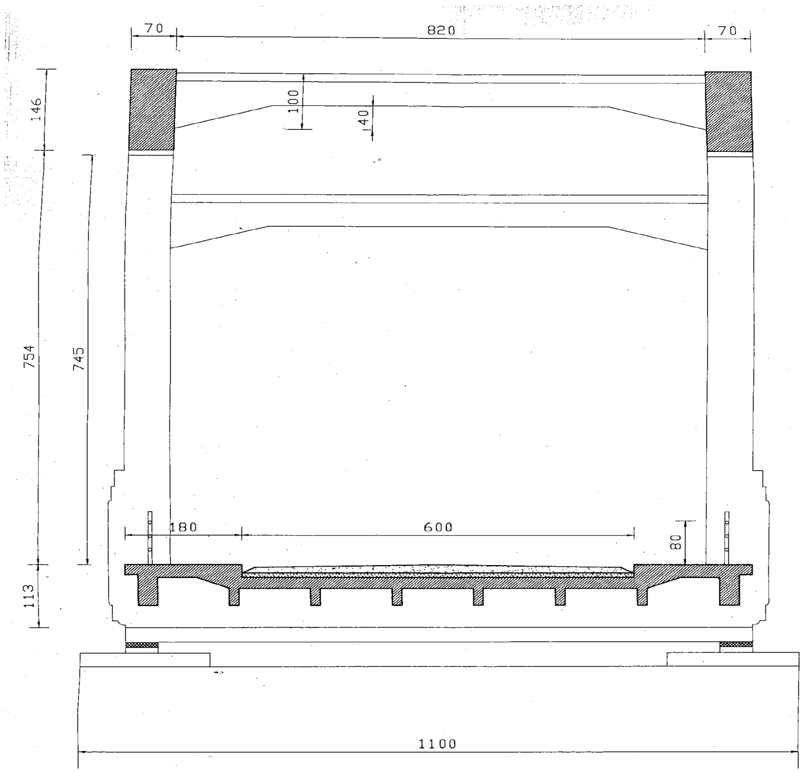

Fig. 4. First span: lateral view.

2. CONDITION STATE OF THE BRIDGE

2.1. Visual inspections

In 2010, during routine inspection (visual inspection) it was assessed that the health conditions of the bridge appeared to be seriously degraded in some specific points of the first span on the West side.

The main defects that were detected were the following:

- Extended crack patterns at the ends of the first and last transversal beams of the first West span, with significant loss of the concrete beam section and corrosion of the reinforcement; the degradation is even worsened in the back faces of the beams, in correspondence to the expansion joints;
- Corrosion of the reinforcement, cracking and expulsion of concrete cover in correspondence to the concrete slab;
- Corrosion and loss of functionality of the structural elements of the bearings.

Fig. 5. *First span: lateral view.*

Fig. 6. *First span: lateral view.*

***Fig.** 7. Existing bearings.*

2.2. Test campaign

In 2011 a test campaign was carried out on the bridge, in order to determine its geometrical and mechanical characteristics, as well as the conservation state of the materials, as required by the code.

The following tests were performed:

- Schmidt hammer test on concrete, in order to evaluate its compressive strength;
- Concrete core boring and laboratory compressive strength test;
- Magnetic test in order to locate the presence of reinforcement inside the concrete;
- Steel reinforcement sample with laboratory traction strength test;
- Chemical tests on concrete to evaluate the content of chlorides, sulfates and nitrates;
- Carbonation tests on concrete cores;
- Measurement of the corrosion potential on steel reinforcement in order to define the potential risk of corrosion.

The results of the tests showed the following:

- Lower values of strength were found in the concrete of the transversal beam and of the chain near the columns (East side of first span), while higher values were recorded in the slab and in the chain near the abutment at the West side;
- the chlorides are in high quantities for all the samples acquired, in 2 cases over 3 over the fixed limit. Even sulfates occur in moderately high amount, in 1 case higher than the fixed limit;
- Carbonation: while the cores extracted from the arch does not show particular carbonation, the transversal beams present high level of carbonation, with thickness up to 9 cm for each exposed face. Even on the slab the carbonation is present, up to about 4 cm;
- Corrosion potential tests show that where the steel is still covered by the concrete, the corrosion potential is low;

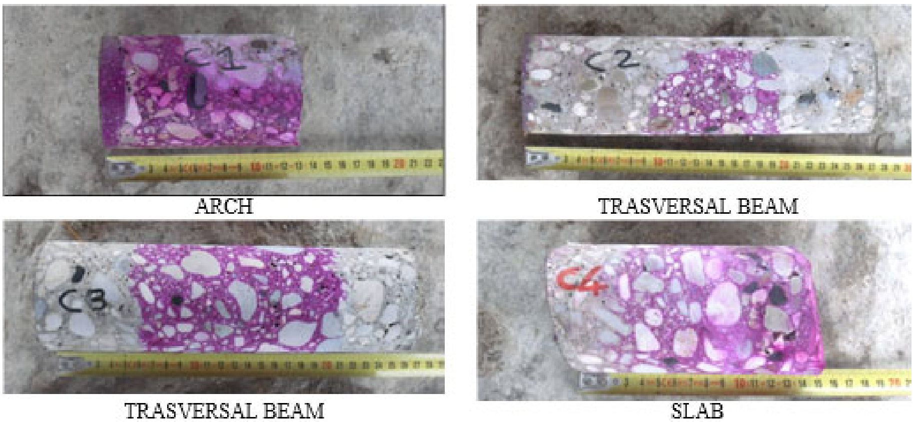

Fig. 8. *Carbonation test.*

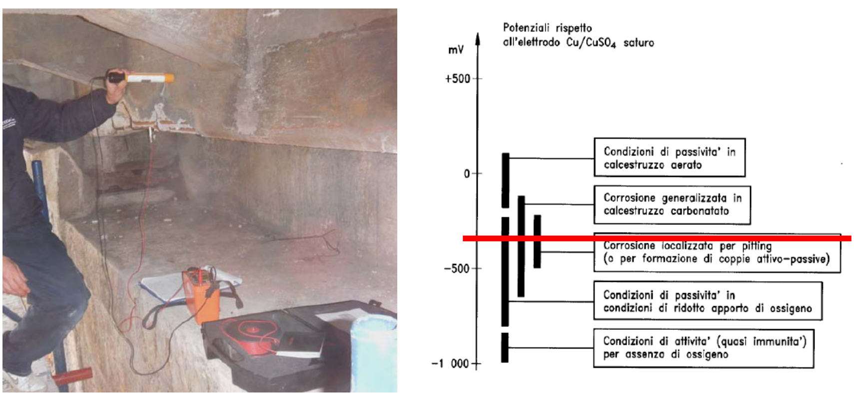

Fig. 9. *Corrosion potential.*

3. ANALYSIS OF EXISTING BRIDGE

Two kind of analysis were performed:

- Global analysis of the structure;
- Local detailed analysis of the damaged parts (transversal beams).

For the global analysis, the verifications were carried out by calculating the solicitation parameters from a finite element model. The model consists of 3230 nodes, 1608 beams, 1701 plates and 394 bricks. The constraints of the bridge are modeled in order to schematize an isostatic system, except for the damaged bearings where sliding was contrasted by the corrosion of the parts.

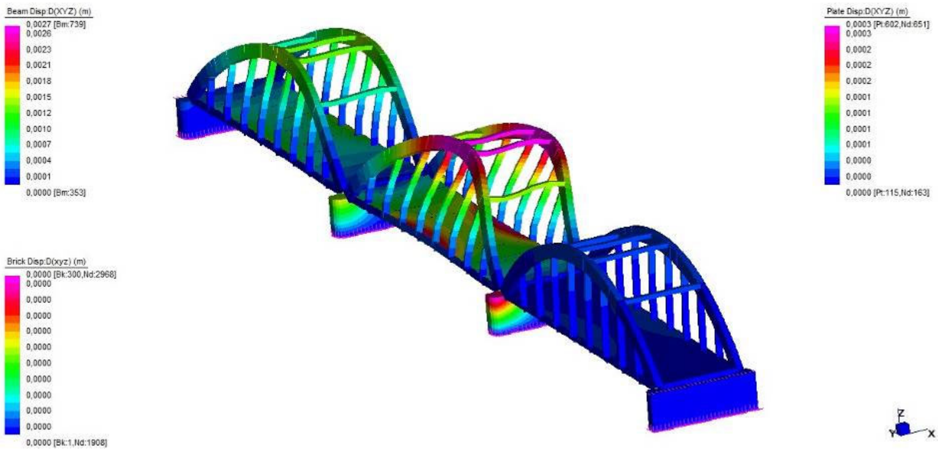

Fig. 10. *FE model of the bridge.*

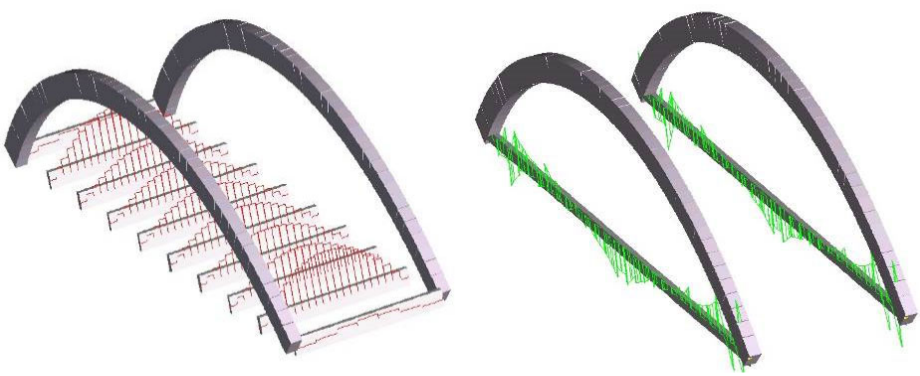

Fig. 11. *Examples of parameters of solicitation.*

The results of the global analysis, showed, as expected, that the capacity of the structural elements is not suitable to resist to the action determined by the recent Italian Code, that involves also a seismic action not considered in the original project of the bridges.

The resistance of the elements is generally exceeded by the solicitations with a factor around 1.5 for the slab and until 10 for the damaged transversal beams.

An intervention was needed.

4. DESIGN OF INTERVENTION

An intervention of global upgrading of the bridge to the new codes was not scheduled by the road network Owner.

The intervention proposed aimed at maximize the local benefit of the damaged elements and of the most vulnerable ones based on the results of the analysis, ensuring minimum discomfort to the bridge functionality.

The designed interventions were the following:

- reinforcing steel structure at the external transversal beams, damaged and deteriorated;
- increase the thickness of the slab with additional reinforcement;
- replacement of supports.

Through the connection of the existing structure with new steel elements it is possible to transfer part of the stresses coming from the external actions to the latter.

This type of intervention is already established in building practice. It is more invasive with respect to the the application of FRP, but leads to lower expanses.

The new steel elements are made up of steel frames connected by bolts to the existing structure, through the use of resins and anchor plates.

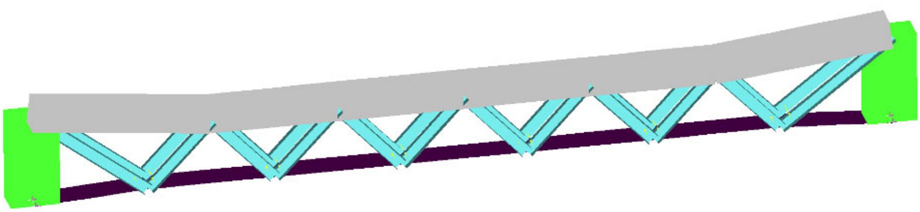

Fig. 12. *FE model of the steel reinforcement.*

5. LIFTING OPERATIONS

The replacement of the supports implied the lifting of the whole first span in order to remove the existing rolling bearings and replace them with new confined elastomeric bearings.

In order to lift the bridge, a system of hydraulic jacks was installed, fixed at the top of the abutments. Since it was not possible to lift the bridge from the external face of the arch, a system of 8 jacks along the transversal beams was installed, after the application of the steel reinforcement.

During the lifting, a continuous check of the distribution of forces along the transversal beam was carried out, in order to avoid excessive solicitation to the beam itself.

Fig. 13. *Application of steel reinforcement.*

Fig. 14. *Lifting system.*

Fig. 15. New bearing and hydraulic jack.

6. CONCLUSIONS

In this paper, it was analysed the structural behaviour of deteriorated and damaged portions of the road bridge on the SP 121 at Km 4+830 in NE Italy.

The verifications carried out showed that the structural elements under investigation (transversal beams, slab, bearings) were not able to provide adequate resistance to the actions provided for by the code. These results were confirmed by deep damage actually found in the structure by inspections.

Local reinforcement interventions were designed and realized on the individual elements. The interventions were the following:

- The increase of the thickness of the slab with additional reinforcement;
- Replacement of the bearings;
- A reinforcement steel frame structure on the transversal beams.

These reinforcements allowed to increase the resistance of individual structural elements that were reinforced, improving statically and seismically the structural behaviour of the local elements.

The replacement of the bearings involved the lifting of the bridge with the use of hydraulic jacks, that allowed to study the local distribution of stresses.

ACKNOWLEDGEMENTS

The acknowledgements goes to Vi.abilità S.p.a. for the support to the design and the realization of the work.