REHABILITATION OF CONCRETE BEAM BRIDGES IN CROATIAN STATE ROAD NETWORK

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Summary

Bridge structures deteriorate with years of use and exposure to adverse environmental impacts and often extensive and emergency rehabilitation measures are required. In periodic maintenance, all bridge components have to be accessible. That challenging task is enabled by the use of special devices and equipment. This paper presents methods of rehabilitation of structural elements in concrete beam bridges employed in the periodic maintenance programme. Several important bridge reconstructions carried out over years until the present day have been given. Methodological approach to rehabilitation of specific damages found in concrete beam bridge structures has been described. Many bridges were reconstructed during war happenings in Croatia, which demanded a special approach to periodic maintenance issues.

Keywords: Bridge, rehabilitation, inspection, deterioration, rehabilitation, beam bridges

1 Introduction

Public roads in Croatia, depending on their social, transport and economic significance are classified into four categories: motorways, state, county and local roads. Routine and periodic maintenance is conducted on public roads and bridges in accordance with relevant legislation in force. The maintenance of Croatian state roads and bridges is managed by Croatian Road Authority, Hrvatske ceste d.o.o. According to Bridge Management System "HrMos", which has been used in Croatia since the mid-nineties of the twentieth century [1,2], bridges are classified into two main groups: the bridges with a span of 2-5 meters or road culverts, and bridges with a span of ≥ 5 meters, or conventional bridge structures. In the year 2012 the Croatian state road network has 823 bridges with span of 5 meters or larger. In the network, there are 699 concrete beam bridges of different age, including 586 bridges with reinforced concrete and 113 bridges with pre-stressed main girders.

2 Modern rehabilitation of concrete beam bridges in Croatia

2.1 Macelj Overpass

Macelj Overpass, built in 1969, is located on the state road D1 just in front of the border crossing with Slovenia. Overpass that is 36.3 m long in total consists of three spans having vertical clearance of 9,57 m+14,13 m+9,52 m. The overpass is 10.80 m wide, with two sidewalks 1.2 m each. The span structure is a continuous reinforced concrete beam, fixed on the piers and abutment beams, designed and constructed in compliance with legislation in force at that time, PTP 5 [3]. The inspection noticed damages of the road formation under the overpass and the upper structure had become overburdened by multiple resurfacing layers that raised the pavement level and even covered the cur bs. The estimated scope of rehabilitation works included removal of the existing asphalt layers, removal of the concrete on sidewalk brackets and deck slab by hydro-modelling, reinforcement of the new deck slab, installation of new railings, construction of reinforced concrete sidewalk brackets, facia beams and deck slab by placing of special polymer modified concrete, repair of cracks in the existing concrete, reconstruction of abutments and installation of new expansion joints.

Special polymer modified concrete has been designed with the purpose to provide strengthening of the span structure, to increase resistance to freezing and salt activity, to increase resistance to wear and tear/abrasion, to renew waterproofing, to increase skid resistance and non-deformability or resistance to rutting. The construction of concrete deck slab that also has a function of a concrete pavement (Fig 1) is rather complex in the preparation of works and it demands stricter quality control during the works, however, the result is considerably increased durability of the structure.

Fig. 1 Macelj Overpass before and after rehabilitation

2.2 The Mokrice Bridge

The Mokrice Bridge across the Krapina river on state road D1 was built in 1962. The bridge has spans with vertical clearance 14,20 m+17,50 m+14,20 m. Total bridge width before the reconstruction was 8.05 m [4]. The span structure of the bridge is a continuous two-hinged frame, supported on two piers on rocker bearings with foundations in the riverbed. The bridge degradation process had already started during construction of the bridge with subsidence of piers which caused delevelling of pavement (Fig.2). A damage worth mentioning was a crack in the foundation of the south pier and a subsidence of structure in that cross section. The pier had an inclination that deviated 4,5 % from the vertical axis, and the pier moved towards the river bed by 23 cm approximately.

Fig. 2 View of the old bridge Mokrice with details of damages in edge beams and pier foundation

Subsidence of the pier resulted in cracks in the deck slab stretching across 2.0 m at each side of the south pier and in deformation of deck slab that measured as much as 15 cm with additional deformations caused by dynamic loads imposed by vehicles. Edge beams of the desk slab were in the worst structural condition. About 30% of the concrete surface in protective layer of the reinforcement was dislodged and the corrosion reduced the cross section of reinforcement by as much as 50%.

Fig. 3 Reconstructed bridge with details of strengthening by fiber reinforced polymer

Reconstruction of the Mokrice bridge carried out in 2012 included removal of the existing deck slab edge beams, sidewalks and facia beams by hydro-demolition, the widening of the bridge to 9.6 m, levelling of deck slab subsidence, waterproofing, drainage, asphalt surfacing, construction of bridge accesses, reconstruction of north pier and construction of the new south pier that consisted in two groups of five piles having length of 10.0 m. Deck slab soffit has been reconstructed and deck slab reinforced using fiber reinforced polymer sheets in places where cracks had appeared along the south pier.

2.3 The Vukovina II Bridge

The Vukovina II bridge, built in 1954 across the Sava-Odra Channel on the state road D30, has five spans 21,5 m each, supported on four pairs of columns. Each column pair has two columns with diameter 100 cm each that are connected by a head beam. The column base is covered by a steel sheet 4 m high that had corroded completely in the parts located in the channel bed. Total length of the bridge is 121.5 m, while the total width is 10.4 m. The bridge inspection carried out in 2007 [5] recorded damages showed as dislodging of large areas of protective concrete from the reinforcement, appearance of cracks and corrosion of reinforcement.

Fig. 4 The Vukovina bridge with details of column damages and strengthening by steel

Upon the removal of damaged parts by hydro-modelling, disintegrated surface of abutments, cross girders and main girders were rehabilitated by mortar modified polymer, while the surface of head beams was repaired by shotcrete. After removal of steel sheets and hydro-demolition, the columns were repaired by new reinforcement and additional concrete layer 20 cm thick.

2.4 Reconstruction of bridges damaged in war activities

Special efforts were made by the Republic of Croatia to reconstruct bridges that had been damaged or utterly demolished in the 1991-1995 period during the Homeland War. According to data [6] on damages resulting from war activities, there were 48 destroyed bridges, and 60 severely damaged bridges, with total area of 116.913,7 m^2, which amounted to 12.3% of the area calculated for all bridges in Croatia at the time. 76% of destroyed or severely damaged bridges were structures on state roads, 16% bridges were on county roads and 8% on local roads.

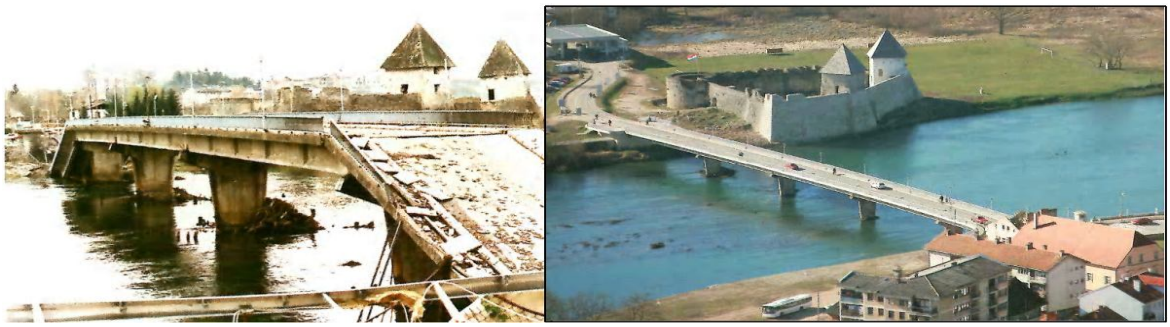

Fig. 5 View of the bridge across the Una at Hrvatska Kostajnica, before and after reconstruction.

The reconstruction of bridges destroyed in war happenings during the Homeland War required specific approach because the explosive devices that had been placed on bearings and supporting structure of the bridge often damaged piers. A good example of such reconstruction is the bridge across the Una river on state road D47 in Hrvatska Kostajnica (Fig. 5). The bridge, built in 1968, has total length of 148 m and it consists of five spans (16 m+4 x 33 m). In the period before 1995 during the first and the fifth span had been demolished in war activities and abutments and piers had been damaged. Reconstruction of the bridge carried out in 2002 included construction of destroyed spans and reconstruction of the existing spans, reconstruction of abutments, piers, expansion joints, drainage and bridge pavement.

3 Optimization of periodic maintenance planning

3.1 Expenditure in periodic maintenance of bridges

The structure of expenditure in bridge rehabilitation in the 2002 - 2010 period presented in Figure 6 is based on data collected on periodic maintenance works carried out within that period. In that period is amounted up to 16.7 million euro [7].

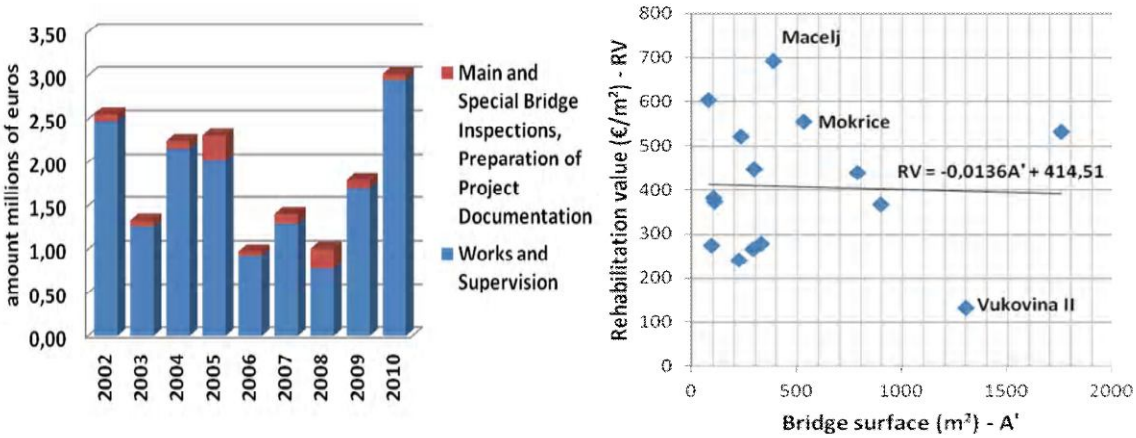

Fig. 6 Periodic maintenance expenditure (2002-2010) and a diagram showing costs of rehabilitation for bridge groups

Data analysis shows that 7% of total expenditure was spent on the main and special bridge inspections, while 93% of expenditure went into works and supervision of works. In the 2002-2010 period the expenditure on the bridges on state roads in Croatia, for the total bridge area of 514.185 m^2 (1538 bridges with span larger than 2 meters) was approximately 32.5 €/m^2. The expenditure for main and special bridge inspections and preparation of design documents was 2,1 €/m^2, while for periodic maintenance works and supervision of works the average expenditure was 30,4 €/m^2.

3.2 Planning of periodic maintenance works

In the Republic of Croatia, periodic maintenance works on the state road network have been planned and implemented on the basis of Public Road Standard and road condition assessment and recommendations made by engineers within Hrvatske ceste d.o.o. Figure 6 shows the relation of expenditure levels for rehabilitation of bridges (€/m^2) and the corresponding area (m^2) for fifteen similar rehabilitation models selected. Rehabilitation costs for the selected group of bridges ranges from 133 €/m^2 to 693 €/m^2. Applying the regression model of rehabilitation cost trend compared to the area of the structure, it can be concluded that the maximum deviation from extreme values in relation to estimated value of regression direction for this group is ±40%. This data tells us that this methodology of estimated costs for periodic maintenance of bridges requires more accurate differentiation of the model in order to be applied. The authors recommend further development of this management model according to types of rehabilitation treatments for homogenous groups of works. When supplemented by data taken in annual and main inspections, this approach enables sufficient accuracy in preliminary assessment of the needed expenditure levels for periodic maintenance of bridges within the network.

4 Conclusion

The work shows some typical examples of bridge rehabilitation (within the inventory of 699 concrete girder bridges) within the periodic maintenance program managed by Hrvatske ceste d.o.o. The paper describes methodological approach to rehabilitation of specific damages typical for such structures. Fifteen similar models of rehabilitation were selected to show the relation of expenditure in bridge rehabilitation (€/m^2) and the corresponding area (m^2). Differentiation of the recommended management model for rehabilitation types with homogenous groups of works, with addition of data collected in annual and main bridge inspections, has implied the development of the model for preliminary assessment of the required expenditure levels for periodic maintenance of bridge network

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