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Original Article

Study and Analysis of Concrete Bridge - Case Study of Bridge 94R

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Abstract *- This summary presents the inspection, assessment, and recommendations for the repair and strengthening of Bridge No. 94R on the national road N2, section Prishtina - Blacë. The objective is to identify optimal methods for repair and reinforcement, taking into account all bridge elements. If applicable, specific alternative methods suitable for this bridge may also be described. Where possible, the repair and strengthening works will be outlined as a set of modular actions, enabling the prioritization of tasks to address the immediate needs for improving the bridge. Priority will be given to aspects such as the main load-bearing beams, traffic safety, and durability. The proposed strategies for the repair and strengthening of Bridge No. 94R have been developed by comparing the bridge's current condition with the requirements outlined in the Eurocodes. This includes the assessment of structural elements and the evaluation of the load-bearing capacity of the bridge.*

Keywords *- Structural load-bearing capacity, Beams, Columns, Concrete, Bridge.*

1. Introduction

Bridge no. 94R consists of three main spans and two side spans, each approximately 7.5 meters in length, and a central span of approximately 3 meters, measured along the axis [1]. The total length of the bridge is approximately 32 meters, and its width is about 8.5 meters. The vertical clearance above the N2 road (National Road) is around 4.6 meters. The bridge serves as an overpass for the road from Ferizaj to Gjilan. It is constructed with a continuous reinforced concrete slab across the three spans, supported by intermediate piers, each consisting of two concrete columns [2]. The bridge was built without visible expansion joints in the superstructure and lacked protective barriers. Pedestrian pathways are provided on both sides of the bridge, secured by protective fencing [3].

2. Study Area

The bridge is located on the outskirts of Ferizaj and is a structural part of the intersection between the N2 national road and the regional road no. 25.3 (Figure 1)[4]. The location of bridge no. 94R is shown on the map below:

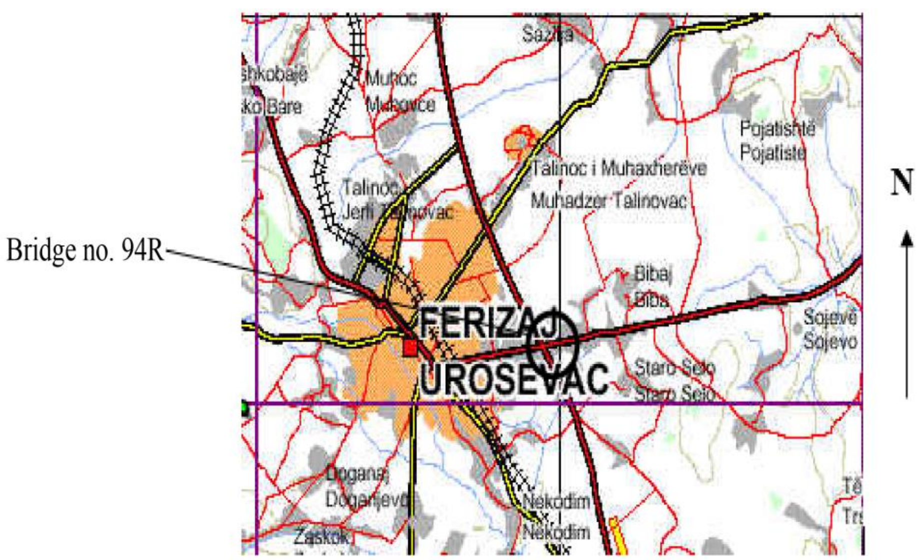

Fig. 1 Position of bridge no. 94R

3. Results and Discussions

The bridge consists of 3 spans: 2 side spans, each approximately 7.5 meters, and 1 main span of approximately 13 meters measured between the supports. The bridge's total length is about 32 meters, while its width is approximately 8.5 meters.

The vertical clearance of the N2 road is around 4.6 meters. The bridge is an overpass of the road from Ferizaj to Gjilan and consists of a reinforced concrete slab, continuous over 3 spans on intermediate supports, each with 2 concrete columns. The bridge is constructed without visible expansion joints in the superstructure and without protective barriers [1, 2, 3].

3.1. Rilings and Sidewalks

Protective barriers and pedestrian paths are secured on both sides of the bridge. Severe damage caused by dynamic loads has been observed at the edges of the slab, leading to the exposure of reinforcement. The lower parts of the side supporting beams show signs of cracking. A sample taken vertically through the bridge platform indicates that the asphalt layer consists of asphalt concrete with a thickness of approximately 70 mm. There is no waterproofing layer between the asphalt and the concrete layer.

The asphalt condition is poor. Transverse cracks have been observed at the edges of the bridge, caused by the lack of expansion or the installation of devices behind the supports. Additionally, there is a lack of skid resistance, asphalt deformations, and some potholes caused by the inappropriate surface material design and the installed material's ageing. The protective barriers along the pedestrian path show signs of corrosion; in some places, they are completely missing.

3.2. Superstructure

The structure generally exhibits poor workmanship with many areas of honeycombing. Some defects have been repaired, but these areas still show signs of poor workmanship and low durability. Based on the observed damages and, consequently, the assessed condition of the superstructure, it is estimated that the load capacity has been reduced by approximately 10% compared to the capacity of an undamaged structure.

The material tests carried out on the structural concrete indicate:

- A significant chloride content.
- The depth of carbonation is 1-17 mm.
- The compressive strength of the concrete is 32 MPa. [4].

3.3. Substructure

The foundations could not be inspected, as no signs of damage to the foundations, such as settlements or cracks associated with supports, were observed. It was therefore considered that no additional special inspections of the foundations are necessary [4].

3.4. Bridge Abutments

At each end of the bridge, slight erosion of the surrounding ground material near the bridge cones was observed. Additionally, there are no visible signs of exposed bridge foundation components or soil covering the foundations [4].

4. Load Capacity Assessment

The load-bearing capacity assessment has been carried out according to Eurocode EN 1992-1:

- Eurocode 1: Basis of design and actions on structures - Part 3: Traffic loads on bridges
- Eurocode 2: Design of concrete structures - Part 1-1: General rules for structures and general rules for bridges - Part 2: Concrete bridges the calculations have been performed according to the ultimate limit state [5].

4.1. Lanes

According to Eurocode, the lane will be divided into a number of notional lanes (normally, the width is 3 m). The number of lanes on the notional roads should be determined as follows:

- The number and location of imaginary lanes shall be determined as follows:
- The location of the lanes is not necessary in relation to their numbering.
- For each individual verification, the number of lanes to be considered as loaded, their location in the field, and their numbering should be chosen so that the effects of the loads are the most unfavorable.
- The lane with the most unfavorable effect is counted as lane number 1, and the lane with the second most unfavorable effect is counted as lane number 2, etc. [6].

4.2. Loadings

Eurocode specifies, among other things, the characteristic values for vertical traffic loads according to the limit state. In the specific loading, Load Model 1 covers the effects of traffic from trucks and cars and is intended for both general and local verifications.

Load Model 1 consists of two parts:

- Concentrated loads with two axles (tandem system), each axle having a weight $\alpha_Q Q_k$. No more than one tandem system per lane should be considered; only complete tandem systems will be taken into account. Each tandem system should be placed in the most unfavorable position in its lane (see Figure 2). Each axle of the tandem system has two identical wheels; therefore, the load per wheel equals $0.5\alpha_Q Q_k$. The contact area of each wheel should be considered square, with a side length of 0.40 m. Only three lanes will be loaded with tandem systems.

- Uniformly Distributed Loads (UDL system) having a weight density per square meter: $\alpha_q q_k$. These loads should be applied only in the unfavorable parts of the influence surface, longitudinally and transversally. q_k = 9 km/m² is related to lane number 1 while q_k = 2.5 km/m² in the remaining lanes.

The adjustment factors α are taken as equal to one. Dynamic amplification is included in the values for Q_{ik} and q_{ik} (Table 1) [6].

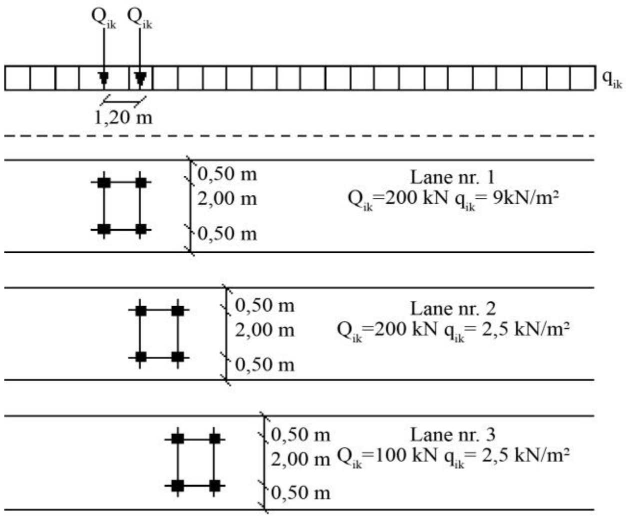

Fig. 2 Charges

Table 1. Results of the loads

Location	Tandem system	UDL system
	Axle loads Q_{ik} (kN)	q_{ik} (kN/m²)
Lane number 1	300	9
Lane number 2	200	2.5
Lane number 3	100	2.5
Other lanes	0	2.5
Remaining area	0	2.5

According to Eurocode 1, the following load combinations shall be considered for the load-bearing capacity assessment:

Superstructure:

1.35·Dead load + 1.35·Traffic load

Substructure:

1.35·Dead load + 1.35·Traffic load + 0.5 · Braking force

4.3. Materials

According to Eurocode 2, Part 2, Concrete Bridges, the following material safety factors shall be used:

- Concrete: 1.50
- Reinforcement: 1.15

A factor α for sustained compression shall also be taken into account. Generally, α may be assumed to be 0.85 [7].

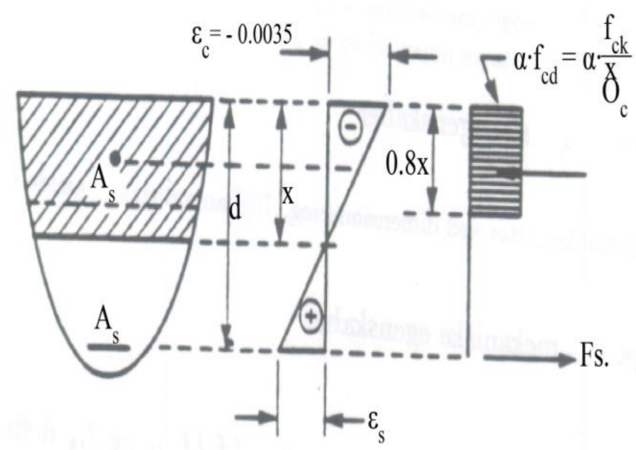

Fig. 3 Rectangular diagram showing α.

Due to the lack of background material, the geometry is based on field measurements. Take into account the results of material tests. Further, the amount of reinforcement in the bridge was estimated based on the approximate design calculation performed according to the 1949 Yugoslav code.

Geometrical parameters - The superstructure is modelled as a 3-span slab with simple supports.

- Span length: 8.2 m, 13.6 m and 7.5 m
- Deck width: 8.6 m
- Carriageway width: 6.5 m
- Number of notional lanes: 2
- Deck height: 0.80 m

Reinforcement diameter: 20 mm (assumed)

Material strength - Based on information and calculations of other bridges, the following strength parameters are used:

- Cubic strength of concrete equal to 30 MPa corresponding to a characteristic concrete cylinder strength of 24 MPa

Reinforcement is equal to St. 37, which is used for main reinforcement on most of the bridges. The characteristic yield tensile strength of St. 37 is assumed equal to 225 MPa .

Utility ratio - Given load combination, geometrical parameters and material strengths, utility ratios of the capacity for the main span and the adjoining spans are calculated.

In the calculation of the utility ratios, the load-bearing capacity is reduced according to the actual condition of the bridge, and please refer to Section 4.2. for additional information (Table 1) [7].

Table 2. Details of Eurocode

Span no.	Utility Ratio (Eurocode)
Adjoining span (pos. moment)	2,7
Main span (neg. moment)	1,7
Main Span (pos. moment)	2.1

The utility ratio shown in above Table 2 is calculated as: $U = M_T/M_u$

Where:
M_u - Ultimate capacity
M_T - Total load effect from the different loads involved in the calculations

Materials - According to Euro code 2, Part 2, Concrete Bridges, the following material safety factors shall be used:
- Concrete: 1.50;
- Reinforcement: 1.15;

A factor α for sustained compression shall also be taken into account. Generally, αit may be assumed to be 0.85 (Figures 4, 5 and 6).

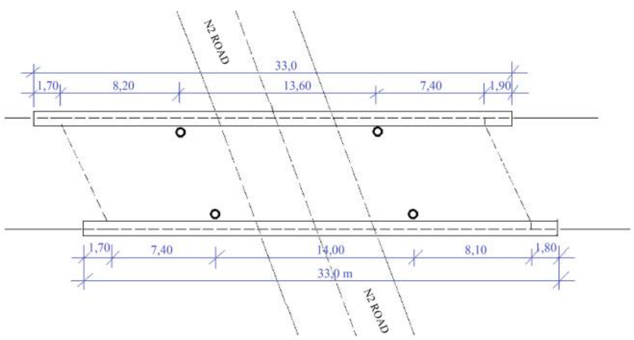

Fig. 4 Plan of bridge

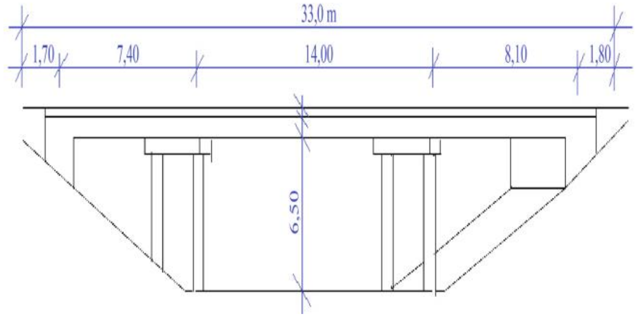

Fig. 5 Elevation of bridge

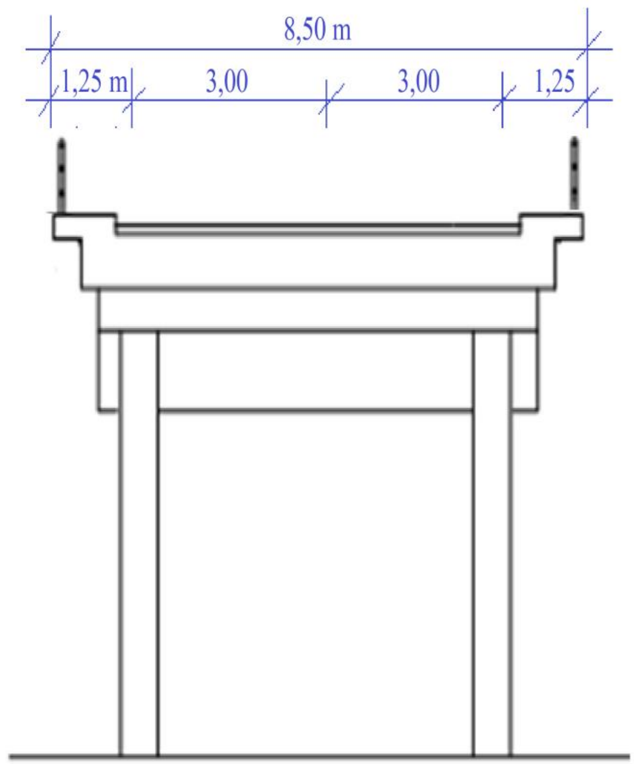

Fig. 6. Cross-section of the bridge

Table 3. Data from the bridge inspection

Category:	Road bridge
Coordinates:	42°22,36 …21°11
Road location	Ferizaj Main Road N - 2
Superstructure type	Multi-span, continual concrete structural slab
Total spans:	3
Length (m):	32
Total width (m):	8.5
Road Width (m):	6.4

Description

Approaches:		**Level 0 (good) to 3 (high severity)**
Asphalt pavement	YES	1
Embankment	YES	1
Guard rail	NO	

Abutments:		**Level 0 (good) to 3 (high severity)**
Type	Cap beams, reinforced concrete cast in situ	0
Joint with deck	NO	
Bearings and pedestal	NO visible	
Backwall	NO	
Wingwalls	NO	

Pier:		**Level 0 (good) to 3 (high severity)**
Pier columns	YES, reinforced concrete cast in situ	0
Cap beam	YES. reinforced concrete cast in situ	0
Pedestals	NO visible	
Bearings	NO visible	
Superstructure:		**Level 0 (good) to 3 (high severity)**
Primary member	Cap beams	0
Deck structural	Reinforced concrete plate cast in situ	1
Joints	NO	
Deck elements:		**Level 0 (good) to 3 (high severity)**
Wearing surface	Asphalt	1
Sidewalk	YES, both sides 1,05	1
Guard rails	NO	
Parapets	YES	1

5. Conclusion

Based on the results presented above, it can be seen that the bridge's load-bearing capacity is sufficient to meet the design requirements according to Eurocode, except for the main longitudinal beams, which are overloaded by approximately a factor of 1.1. The stability of the retaining walls is insufficient. Due to severe damage to the lower part of the superstructure and substructure, exposed and corroded reinforcement, and many areas of exposed inadequate concrete, the load-bearing capacity is reduced, and the structures need to be repaired. Traffic safety is low due to severe scratches on the asphalt. Furthermore, if the asphalt is not continuously repaired, it will be completely damaged during winter, posing risks of accidents and traffic blockages during repairs. The protective railings do not comply with the 10-ton guardrail requirements of Eurocode. The durability and remaining life of various bridge elements have been significantly reduced due to damage and lack of maintenance. The inadequate protective concrete cover to shield the reinforcement in the concrete structure, if not repaired, will reduce the remaining lifespan of the bridge by a factor greater than 3, potentially translating into a reduction of more than 20 years. It can be seen that the waterproofing of the bridge was not done properly or has been damaged during its use.

5.1. Necessary Repairs/Reinforcements

The aspects mentioned in the above sections require several repair and reinforcement works.

5.2. Urgent Repair Works

To avoid traffic accidents and blockages caused by continuous deterioration and necessary winter repairs:

- The asphalt must be repaired by adding a new asphalt layer and covering potholes on the surface.

- The duration of these repairs should be limited to 14 days, during which traffic in both directions will use a single lane controlled by traffic lights.

5.3. Required Repair/Reinforcement Works

To ensure the bridge's functionality, adequate load-bearing capacity, and proper durability of various bridge elements, the following repair/reinforcement project must be carried out:

- Repairing and painting the protective railings. (A better but more expensive alternative is replacing the existing railings with new ones that comply with Eurocode).
- Replacing sidewalks, asphalt, and mortar layers with a reinforced concrete deck integrated with the existing structure, paved with epoxy asphalt. This includes repairing and composite bonding of the deck slab with the side beams. (This will sufficiently strengthen the superstructure).
- Replacing the asphalt up to the bridge, including the expansion joints at the ends of the bridge.
- Cleaning and creating drainage from the concrete base near the supports.
- Repairing the retaining walls and stabilizing them with ground anchors, including the stabilization of supports.
- Removing carbonized concrete, repairing damage, and adding sufficient cover to the reinforcement for the lower part of the superstructure – deck, transverse beams, and main longitudinal beams – and the substructure – columns, foundations, and supports.

The construction period should be limited to 6 months, during which the bridge will be closed to traffic. Traffic will be diverted via a temporary detour, including a temporary bridge over the river. The main parts of the repair and reinforcement works are illustrated in (Figure 7).

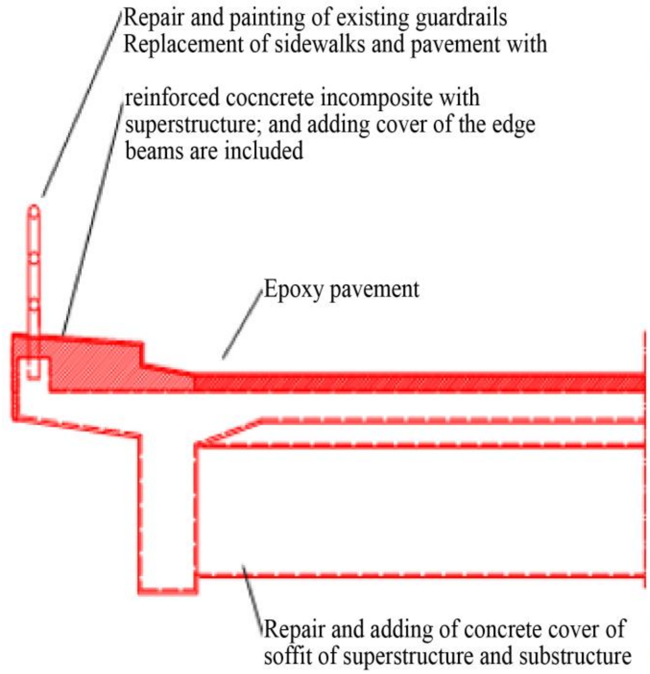

Fig. 7 Cross – Section of bridge, repair and strengthening works

References

[1] Naser Morina, "Works to Strengthen the Existing Bridge on the N2 Road," *Knowledge-International Journal*, vol. 30, no. 3, pp. 631-635, 2019. [Google Scholar]

[2] Naser Morina, "Reinforcement of the Bridge Rabovce," *Knowledge-International Journal*, vol. 31, no. 3, pp. 805-809, 2019. [Google Scholar]

[3] Naser Morina, "Strengthening of the Concrete Bridge," *Knowledge-International Journal*, vol. 43, no. 3, pp. 615-620, 2020. [Google Scholar]

[4] Jure Radic et al., *Concrete structures in Croatia*, Croatian Society of Structural Engineers, 2006. [Publisher Link]

[5] Folić Radomir, "Review of Research in the Function of Structural Engineering Development in Serbia," *Building Materials and Structures*, vol. 64, no. 1, pp. 59-77, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[6] Jure Radić, and Goran Puž, *Bridge Engineering in Croatia*, 1st ed., CRC Press, 2013. [Google Scholar] [Publisher Link]

[7] B. Mazić, and I. Lovrić, Highways, Faculty of Civil Engineering University of sarajevo, Sarajevo, 2010.