IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 14, Issue 5, May 2024, ||Series -1|| PP 50-56

Analysis Concrete bridge- Case study in Kaçanik

Naser R. Morina[1*]
[1] *Faculty of Civil Engineering and Infrastructur, University for Bussines and Technology, Prishtina, Republic of Kosovo,*
[*]*Corresponding author: naser.morina@ubt-uni.net ; morina.n@hotmail.com*
Received 12 May 2024; Accepted 29 May 2024

Abstract: The summary covers inspection, assessment and recommendations of repair and strengthening works for bridge no. 45 on N2 Road, Pristina - Blace section.
Load capacity calculations have been carried out based on the results from Study and Detailed Inspection and have shown that the capacity is insufficient. Special load capacity assessment has been carried out considering loads representing the present traffic. Results have shown that no traffic restrictions need to be established. The findings of this detailed inspection are that the condition is not good due to poor execution of works and lack of routine maintenance.
Key words: Bearing Capacity, Buildings, Structures & Design, Columns.

I. Instruction

The bridge is assumed originally constructed in 1967. The bridge, a reinforced concrete arch structure, consists of 13 spans of the superstructure parted in 3 continuous sections by 2 charniers, one at each end of the arch span. The superstructure is supported on 2 abutments, 9 pair of columns and 3 pair of supports at arch tops with an overall length of approx. 180 m. The width of the bridge is approx. 9,5 m. The length of the arch span is approximately 85 m and placed asymmetrical with only one superstructure span length from the northern abutment (MI, 2008). The pavement is asphalt, 1 layer only. The taken out core indicates a thickness of approx. 6 cm. In the bottom of the asphalt layer parts of a 0.5 mm metallic plate are found. Between the asphalt and the structural concrete a mortar layer is cast, 3 mm welded reinforcement net. The taken out core indicates a thickness of approx. 3 cm. The pavement is drained through gutters and outlets in the bridge along sidewalks. Sidewalks, are elevated approximate 150 mm above road level. The monolithic superstructure includes 2 longitudinal main girders with cross girders and deck extended as wings over the main girders for sidewalks. The monolithic substructure includes 2 abutments and 6 pairs of columns founded directly in ground. The structure is based directly on ground/rock. The bridge is constructed with expansion joints at each abutment at the bridge ends and at the 2 charniers in the superstructure above the arch ends. The bridge is supported at rocking concrete bearings under each longitudinal main girder at the abutments. The bearings are placed in a basin constructed as a part of the abutment. At the northern charnier is shifted to new neoprene bearings, at the southern charnier rocking concrete bearings are used (MI, 2008; Čolić and Ristovski, 2016).

The study area is located in the southern part of the Republic of Kosovo (Figure 1). The bridge is located approximately 60 km. south of Prishtina near the North Macedonian border. The bridge is in the road N-2 road in 2 lanes of 3.75 m and 2 side-walks of 0.9 m over a deep valley (Figure 1)(MI, 2008).

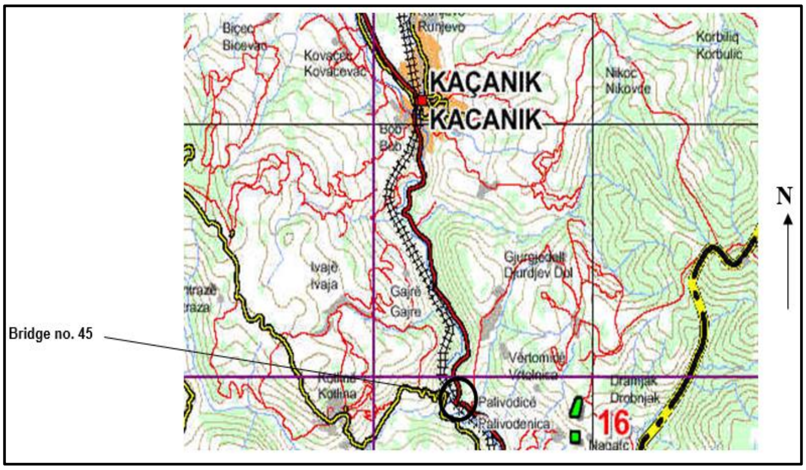


Figure 1. Position of the study area.

II. Materials And Methods

When damage occurs, the decision-making process regarding whether to repair, rehabilitate, or replace the girder is typically challenging. Repair methods and procedures for each damage class are then presented for each damage type. Previous repair cases done are documented and their performance is evaluated by visual inspection records. Ultimate limit state structural calculations (Mazić and Lovric, 2010). Given load combination, geometrical parameters and material strengths, utility ratios of the capacity for the main span, the adjoining spans and the arch are calculated. The load capacity for the superstructure and the arch respectively is reduced according to the actual condition as described in section 4.2. In this section, the properties of the materials used in this project will be presented. The adhesive plays the most important role in the rehabilitation with bonded CFRP (Carbon Fiber Reinforced Polymer) strips since the adhesive has to transfer the load from the steel flanges to the CFRP strip and the adhesive is usually the weakest link in bonded systems. If the adhesive fails prematurely, including adhesive and cohesive failures, the high strength of the CFRP strip cannot be utilized efficiently. In addition, the effectiveness of the rehabilitation depends on the stiffness and the strength of the CFRP strip. CFRP strips with high stiffness are able to increase the moment of inertia of the section being rehabilitated, reducing the stress at a crack tip. Use of a strip having high strength can increase the moment capacity of the section. Furthermore, adhesive strength could vary depending on the materials to be bonded, indicating the importance of obtaining the right combination of adhesive and CFRP strip (The "Bridge Assessment"- Raport, 2004).

Table 1. Calculated utility ratios (The "Bridge Assessment"- Raport, 2004).

Span no.	Utility Ratio (Eurocode)
Longitudinal T-beams at mid span	1.3
Longitudinal T-beam at support	0.7
Cross beam, support	0.8
Cross beam, mid span	0.6
Deck	1.0
Arch	1.4

The utility ratio shown above in Table 1. is calculated as: U = MT/MU, where:
Mu-Ultimate capacity
MT-Total load effect from the different loads involved in the calcula-tions.
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 α may be assumed to be 0.85 (Figure 2) (The "Bridge Assessment"-Raport, 2004).

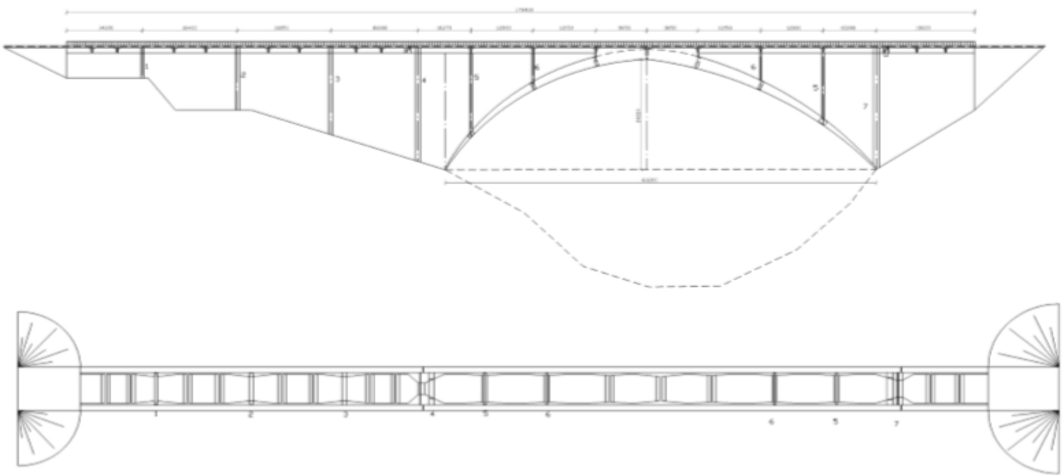
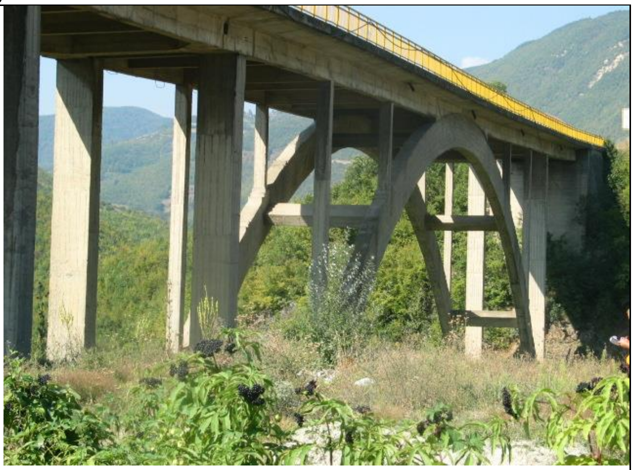


Figure 2. Longitudinal section and plan (The "Bridge Assessment"-Raport, 2004).

Table 2. Bridge Nr. 45

Category:	Road bridge	
Coordinates:	42°10,53 …21°16,19	
Road location	Ferizaj – Hani i Elezit Main Road M - 2	
Superstructure type	Multi span, continual concrete structural slab	
Total spans:	7	
Length (m):	206	
Total Width (m):	10	
Road Width (m):	7.6	

DESCRIPTION

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

Abutments:		*level 0 (good) to 3 (high severity)*
Type	Full height	0
Joint with deck	YES	1
Bearings and pedestal	YES	0
Backwall	YES	0
Wingwalls	YES	0

Pier:		*level 0 (good) to 3 (high severity)*
Pier columns	Arch beam and columns	0
Cap beam	YES	0
Pedestals	YES	0
Bearings	YES	0

Superstructure:		*level 0 (good) to 3 (high severity)*
Primary member	Trans. And longitu. Beams R. C .	0
Deck structural	Reinforced concrete plate cast in situ	0
Joints	YES	1

Deck elements:		*level 0 (good) to 3 (high severity)*
Wearing surface	Asphalt	1
Sidewalk	Yes both sides 1,20	1
Guard rails	N0	
Parapets	YES	1

III. Results and Discussions

Detalied Inspection-for detailed inspection of soffit of the superstructure above the ravine with river, a mobile platform erected from the bridge was used. Detailed inspection of the arches was made by a mountain climber hanging down from the guard rails. The quality of the concrete was estimated by use of Schmidt hammer. The concrete cylinder strength corresponds approximately to 40 MPa (The "Bridge Assessment"- Raport, 2004). Guard rails-painting is in poor condition, with rust spots overall through the paint and deep corrosion in some areas, especially at the sceptres where fixed into the edge beams. Many steel profiles are deformed/broken/missing caused by traffic impacts (The "Bridge Assessment"- Raport, 2004). Sidewalks-a few curb stones of rock are eroded by freeze - thaw. Asphalt pavement has some holes and growing plants. Edge beams cover is too small, as some reinforcement, especially the reinforcement closest to the drip nose are exposed. Concrete is spalling to some extent, especially behind guard rail sceptres which have been impacted by traffic and around exposed and corroding reinforcement (The "Bridge Assessment"- Raport, 2004). Pavement and mortar layer-the outlets and gutters of the bridge are not clean. Asphalt pavement up to and on the bridge are heavy cracked - especially in the south going lane - and heavy rutted - especially in the north going lane. Further some holes are developed caused by the heavy cracking. The deck is without waterproofing. A core drilled out vertically in the bridge deck shows that the pavement consists of 1 layer of asphalt concrete, actually measured to 60 mm, based on a reinforced mortar layer, measured to 30 mm. There is no bonding between the mortar layer and the structural concrete below. Only minor leakage through deck is observed (The "Bridge Assessment"- Raport, 2004). Superstructure-of monolithic reinforced concrete - deck with extended wings for sidewalks, longitudinal main girders and cross girders - is without sufficient cover, if any, as reinforcement is exposed to some degree. Cold joints and other not proper poured concrete areas with open stones and reinforcement are found, especially at the underside of main girders with dense reinforcement. In each deck section, including wings, are one or more cracks perpendicular to bridge axis at its underside, probably caused by shrinkage. The deposits of calcium, caused by leaking through the deck and or condensed water, seems not to be of importance. In each main girder, especially in the middle of its spans, minor vertical cracks caused are found by load. The material tests carried out for the structural concrete of the deck indicate:

- estimated compressive concrete strength of 50 MPa;
- the depth of carbonisation from the soffit is 19-26 mm;
- the content of chloride is not critical, measured to 0,04% of concrete mass;
- many minor cracks, possibly caused by freeze-thaw actions or alkali aggregate reactions;

It is estimated that the load capacity is reduced by 20% due to the damages as observed during the inspection.

Substructure of reinforced concrete - abutments, columns and arches - is without sufficient cover, if any, as reinforcement is exposed to some degree, at underside of arches in heavy degree. Cold joints and other not proper poured concrete with open stones and reinforcement areas are found, at underside of arches in heavy degree. Spalling concrete is found caused by corroding reinforcement, especially at underside of arches. The abutment walls have eroded surface areas and leaking water from the basin for rocking concrete bearings and with some moss. The material tests carried out of the structural concrete of an arch indicate:

- homogeneous concrete of reasonable quality with an estimated compressive concrete strength of 32 MPa;
- the depth of carbonisation is 19-34 mm;
- the content of chloride is about 0;

It is estimated that the load capacity is reduced by 20% due to the damages as observed during the inspection (The "Bridge Assessment"- Raport, 2004).

Load Capacity Assessment-the Euro code specifies among other things characteristic values for vertical traffic load in the ultimate limit state. In specific Load Model 1 covers the effects of the traffic of lorries and cars and is intended for both general and local verifications (Čolić and Ristovski, 2016).

Load Model 1 consists of two parts:

a) Double-axle concentrated loads (tandem system), each axle having a weight: $\alpha_Q Q_k$. No more than one tandem system should be considered per lane; only complete tandem systems shall be considered. Each tandem system should be located in the most adverse position in its lane, see Figure 3. Each axle of the tandem model has two identical wheels, the load per wheel being therefore equal to $0.5\alpha_Q Q_k$. The contact surface of each wheel is to be taken as square and of side 0.40 m. Only three lanes shall be loaded with tandem systems (Mazić and Lovric, 2010).

b) Uniformly distributed loads (UDL system) having a weight density per square metre: $\alpha_q q_k$. These loads should be applied only in the unfavourable 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} (Mazić and Lovric, 2010).

Table 3. Basic values (Mazić and Lovric, 2010).

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

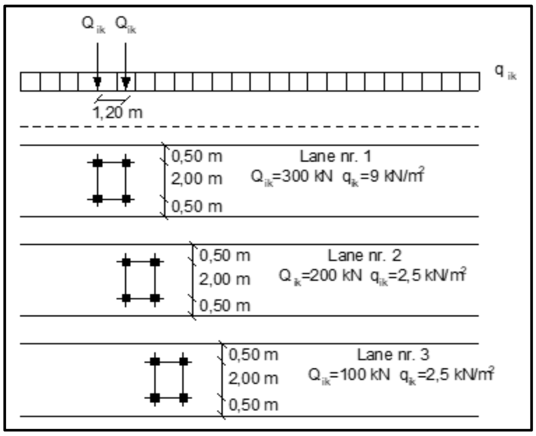


Figure 3. Load Model 1 according to Euro code (Mazić and Lovric, 2010).

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 α may be assumed to be 0.85 (Radic, 2010).

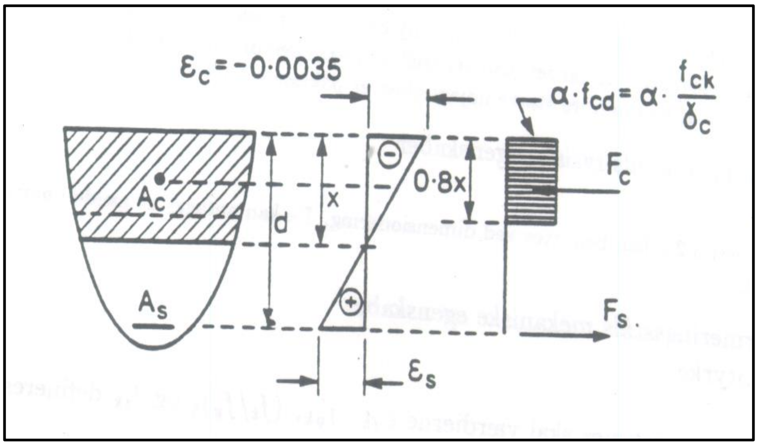


Figure 4. Rectangular diagram showing α (Radic, 2010).

Material strength-no drawings or design calculations could be found for this bridge. However, it is assumed that strength parameters are the same as found for bridge no 43 and 44.

- Cubic strength of concrete equal to 30 MPa corresponding to a characteristic concrete cylinder strength of 24 MPa
- Reinforcement 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 (MI, 2008).

Special Inspection and Load Text-the load capacity of the bridge as determined and described in section 5 is considered to represent the load bearing capacity with sufficient accuracy as:

- The bridge is designed at the same time as bridge no. 43 and 44 which is well-documented. Thereby the same design basis is used
- The superstructure is constructed at the same principles as bridge no 43 and 44
- The static behaviour of the bridge is simple and the analysis model used for the load bearing capacity calculations is therefore considered accu-rate.

Based on these items, the information for the load capacity assessment is con-sidered adequate to determine a reliable load capacity. This was not foreseen in the Inception Report.
It is therefore not expected that a loading test for bridge no. 45 would benefit the assessment of the load bearing capacity and consequently no loading tests have been carried out for the bridge (Stankovic and Przulj, 2012).
Repair and Inspection-based on the results shown it can be seen that the load bearing capacity of the bridge is sufficient to meet the design requirements of the Eurocode except for the longitudinal main girders and arches,

which are overloaded approximately by a factor 1.1 and 1.2 respectively. Due to heavily damaged underside of arches with no cover, exposed and corroding reinforcement and lots of open not proper concrete areas, the load capacity is reduced, approximately estimated by 20%, and the arches have to be repaired in order to raise it. As a result of badly deteriorated rocking concrete bearings at the southern charnier of superstructure, the load capacity is reduced. It is necessary to shift the bearings and repair the related consoles of the superstructure in order to increase it (Stankovic, 2012).

IV. Conclusion

Load Capacity-based on the results it can be seen that the load bearing capacity of the bridge is sufficient to meet the design requirements of the Eurocode except for the longitudinal main girders and arches, which are overloaded approximately by a factor 1.1 and 1.2 respectively. Due to heavily damaged underside of arches with no cover, exposed and corroding reinforcement and lots of open not proper concrete areas, the load capacity is reduced, approximately estimated by 20%, and the arches have to be repaired in order to raise it. As a result of badly deteriorated rocking concrete bearings at the southern charnier of superstructure, the load capacity is reduced. It is necessary to shift the bearings and repair the related consoles of the superstructure in order to increase it.

Traffic safety-the traffic safety is poor as a result of the very heavy rutting of the pavement and the holes in it. Furthermore the pavement will, if not repaired continuously, be totally damaged throughout the winter, causing risk of traffic accidents and traffic blocking during repair.The guard rails are not in accordance with the 10 ton Eurocode guard rails.

The impact capacity of the guard rail, estimated to approximately 1,5 ton, corresponds nearly to a 2 ton Eurocode guard rail and combined with a high curb stone, 150 mm, along the road, the actual condition seems to be acceptable at least for a period of years [9].Durability-the durability and the remaining lifetime of the different elements of the bridge are highly reduced due to the damages and missing maintenance. The remaining lifetime of the bearings at the southern charnier of the superstructure has almost expired. The missing cover of reinforcement in the concrete structure, if not repaired, will reduce the remaining lifetime of the bridge with a factor higher than 2, for the arches higher than 3, corresponding to, probably, a reduction of more than 20 years. The lifetime of the pavement, including waterproofing, has expired. Repair/Strengthening works-the aspects mentioned in sections above require some repair and strengthening works. Acute repair works: In order to avoid traffic accidents and traffic blocking caused by continuous deterioration and necessary repair during winter: The pavement should be repaired by adding a new temporary wearing coarse after milling of the surface for rutting

Needed repair/strengthening works: In order to secure functioning of the bridge, sufficient load capacity and proper lifetime of the different elements the following repair/strengthening project should be carried out:

- Repair and painting of guard rails. (A better, but more expensive, alternative is to replace the existing guard rails with new 10 ton ones in accordance with the Eurocode),
- Replacement of sidewalks, pavement and mortar layer with reinforced concrete deck in composite with existing deck structure, paved with epoxy. This includes repair and composite connection of the plate to the edge beams. (This will strengthen the superstructure sufficient)
- Replacement of pavement up to the bridge including of expansion joints at the bridge ends and at the charniers.
- Cleaning and establishing of drain from rocking concrete bearing basins at abutments.
- Repair of consoles and shifting of bearings at southern charnier of superstructure. (This will secure the load capacity and increase the lifetime essentially).
- Removal of carbonised concrete, repair of damages and adding sufficient cover of the underside of superstructure - deck, cross girders and longitudinal main girders - and substructure - columns, foundations and abutments. (This will increase the lifetime essential).
- Removal of carbonised concrete, repair of damages and adding reinforced concrete of approximately 100 mm of the sides and underside of arches. (This will strengthen the arches sufficient and increase the lifetime essential).

References:

[1]. Ministry of Infrastructure of the Republic of Kosovo. (2008). Department for Projects
[2]. Ministry of Infrastructure of the Republic of Kosovo. (2008). Department for execution.
[3]. Čolić P, Ristovski A. (2016), Reinforced concrete bridges - page 21 – 25
[4]. Mazić; B. , Lovric I., Roads (2010). Book, page 252 - 256
[5]. Mazić; B. , Lovric I., Roads (2010). Book, page 256 – 260
[6]. Radic J., Concrete Structures (2010). Book, page 242 – 244
[7]. counselling 04-06 June 1997 page 141 – 145.

[8]. Stanković S. (1997). Conducting rehabilitation works on concrete bridges -Yugoslavian counselling 04-06 June 1997 page 309 – 314.
[9]. Pržulj M. Bridge (2012). Book, page 452 - 460
[10]. The "Bridge Assessment" (2004). Raport- Project was carried out after the program described in the Initial Report.