Structural Investigation of Drini River Bridges, Case Study of Structures Analyses

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Abstract: - The Drini is the longest river not only in Albania, but in the west Balkan region, with a total length of 285 km. It is well known for a lot of number and famous bridges constructed since the antiquity period and continuing nowadays. This paper is focused on the structural development of bridges that used to be called "Kukësi Bridges" located over the White and Black Drini rivers. The old bridges were built and designed in 1974 using KTP Albanian national codes, carrying the first-class road until the building of a national road. The new bridge is in the final construction stage with the reconstruction of the national road highway, designed with advanced requirements regarding Eurocode standards. This paper analyses the structural bridges' progress related to historical and technical points of view.

Key-Words: - Bridges structure, Eurocode loads, Technical design code of Albania, Drini river bridges, Historical bridges, bridge geometry, standard, load model.

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1 Introduction

Historical investigation of Albanian structural bridges may be characterized by the fourth development era. In the first period of the Antiquity era, three types of bridges structure were constructed, [1]:

1) wood bridges with stone abutments;
2) one archway stone arch bridge (Çobanaj, Kushi, Muriqan, Kasabashi, Sharova bridge, etc.);
3) multi-archway stone arch bridges (Bashtova, Qukesi, Goliku bridge, etc.).

The second period in the Middle Ages era (VII and XV century) is not characterized by any special structure bridges. The third period, between the XV and XIX centuries, built 72 cultural monument bridges (Mesi bridge on Shkodër, Veziri bridge on White Drini River, Velabishti bridge on Berat, Luma bridge on Drini River, etc.), [1]. The fourth period of the XX century, has been characterized by the building of concrete, reinforcement concrete and prestress bridges designed with technical Albanian codes, [1]. The 1990s years and nowadays, are characterized by the great development of road infrastructure in the period designed and constructed according to Eurocode requirements, [2]. Previews structural investigation studies have been presented that it's important to understand and identify the historical structure evaluation and development, [3], [4], [5].

This paper described a structural investigation of the old and new 'Kukësi" bridge on the Drini River. Figure 1 shows an illustration view of the two bridges.

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Fig. 1: Old and new bridge over Drini River illustration

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2 Traffic Moving Loads and Material with Technical Albanian Codes

Old "Kukësi bridges" were built in the 1974 year, situated over the Black and White Drini Rivers carrying the first class road before the construction of the national highway Albanian road, currently the second highway road. It is a four-span girder beam-type scheme. The substructure was designed as a reinforced concrete monolithic construction system on a supported span with a cantilever length of 50.28 m over the pile and prefabricated beams with a 30.6 m length on the middle bridge span. Piles no. 1 and no. 2 are realized using a four-column bridge system with φ = 2.4 m diameter dimension. Columns have been realized with Fe-44k steel reinforced bar and C20/25 concrete class. C12/15 concrete class and st-3 reinforcement steel are used for plinth foundation construction. Longitudinal profile views of the bridge set out on the White and Black Drini Rivers are presented in Figs 2 and 3. Cross sections 1-1 and 2-2 used on middle and supported span bridge length, respectively, are shown in Fig. 4.

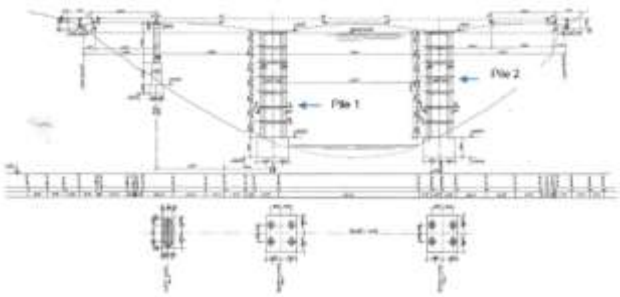

Fig. 2: Longitudinal profile and plan view of bridge over Black Drini River

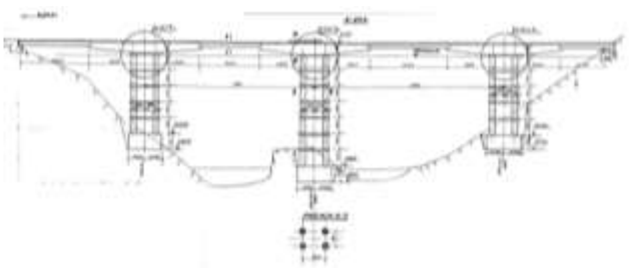

Fig. 3: Longitudinal profile and plan view of bridge over Black Drini River

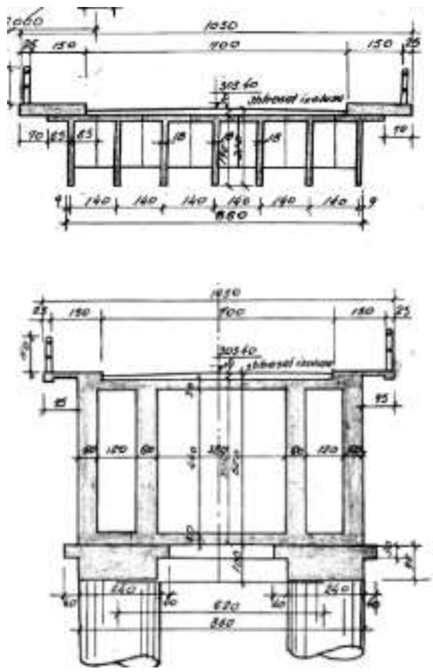

Fig. 4: Cross Section bridge 1-1, 2-2 on middle and supported span length

According to KTP Albanian codes, the N-300 traffic moving load scheme is used for highway road type A calculations, which is composed of a range of loads with a distance of 10 m equally dispersed. The total vehicle value weight is Pi= 300 KN. K-800 control load scheme is the only vehicle with an 800 KN weight load. Figure 5 shows N-300, K-800 moving and control load schemes respectively, [6], [7].

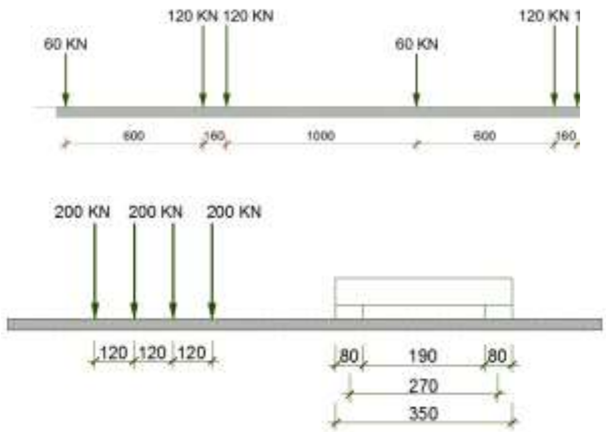

Fig. 5: Traffic moving load N-300 and K-800 based on KTP codes, [7]

3 Traffic Moving Loads and Material with Eurocode. New Bridge over Drini River Case Study

The New Drini Bridge, designed for the reconstruction of the national highway road, consists of three spans, spans 20+270+20 length respectively. The main structure has a total length of 23.213 m and two side platforms with a width of 1.762m. Figure 6 presents a typical bridge cross-section along the arch length. A longitudinal view of a new bridge is shown in Figure 7.

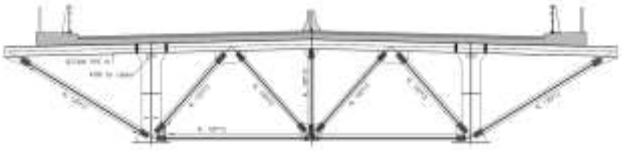

Fig. 6: Typical bridge cross-section along the arch length

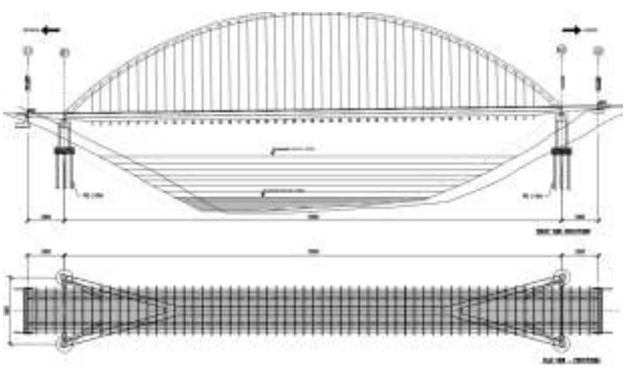

Fig. 7: Longitudinal view of the new Drini Bridge

The indicative design working life for the new bridge is 100 years, for the number 5 category of monumental bridge structures as it is shown in Table 1, according EN 1990:2002, [8], [9].

Table 1. Indicative design working life EN 1990:2002, [8]

Design working life category	Indicative design working life (years)	Examples
1	10	Temporary structures
2	10 to 25	Replaceable structural parts e.g gantry girders, bearings
3	15 to 30	Agricultural and similar structures
4	50	Building structures and other common structures
5	100	Monumental building structures, bridges, and other civil engineering structures

Mechanical properties of steel grades are presented on Table 2.

Table 2. Mechanical properties of steel grades, EN 10025-2:2004 [10]

Mechanical properties	
Young modulus:	E = 210 000 N/mm^2;
Shear modulus:	G = E / [2(1+ν)] = 80770 N/mm^2;
Poisson ratio:	ν = 0,3;
Coefficient of thermal expansion:	α = 12 × 10^{-6} for °C^{-1};
Density:	ρ = 7850 kg/m^3

Slip-resistant bolted connections on serviceability limit states are designed regarding EN 1993-1-8, [10], [11], [12], B category. The preloaded designed force of M27 bolts is verified by $F_{(p,\ cd)}$=290 kN. The slipped coefficient of bolted connections k_s is equal to 0.41. The ultimate limit states verification capacity is done for A category according to EN 1993-1-8, [13], [14], [15].

Slip designed with preloaded bolted resistance:

$$F_{s,Rd} = \frac{k_s \mu F_{p,c}}{\gamma_{M5}} = 106\ kN \qquad (1)$$

where, $F_{s,Rd}$ = is the resulted bolt related shear load,

μ = is the friction coefficient,

γ_{M5} = is the safety factor.

Slip designed for bolted resistance to all slipped plans:

$$F_{v,Rd} = \frac{\alpha_v f_{ub} A}{\gamma_{M2}} = 275\ kN \qquad (2)$$

where α_v is the coefficient of thermal expansion,

$f_{ub}{}^A$ is the steel tensile stress,

γ_{M2} = is the safety factor

Shear resistance of bolted connections plan is limited to 2/3 of the resulting bolt $F(v, Rd)$:

$$F'_{v,Rd} = 184\ kN \qquad (3)$$

Reinforced steel class is taken B450C, [13], according to Eurocode requirements. Mechanical properties of steel grades and reinforced concrete C40/50 are shown in Tables 3 and 4, respectively [16], [17], [18], [19], [20].

Table 3. Mechanical properties of steel grades

Steel B450C			
E_s	Young modulus	200 000	N/mm²
γ_s	Safety factor	1,15	
f_{yk}	Characteristic yield strength	450	N/mm²
f_{yd}	Design yield strength	391,30	N/mm²
ε_{ud}	Ultimate strain	0,0675	
ε_{yd}	Elastic limit strain	0,0022	

Table 4. Mechanical properties of reinforced concrete C40/50

Concrete C40/50			
R_{ck}	Characteristic concrete cube compressive strength	50	N/mm²
f_{ck}	Characteristic concrete cylinder compressive strength	40	N/mm²
γ_c	Partial factor	1,5	
f_{cm}	Mean value of concrete cylinder compressive strength	48	N/mm²
f_{ctm}	Mean value of axial tensile strength	3.5	N/mm²
E_{cm}	Young modulus	35 000	N/mm²
f_{cd}	Design compressive strength	26.7	N/mm²
f_{ctk}	Characteristic tensile strength	2.5	N/mm²
f_{ctd}	Design tensile strength	1.7	N/mm²

Figure 8 presents a parabola rectangle diagram adopted for concrete verification.

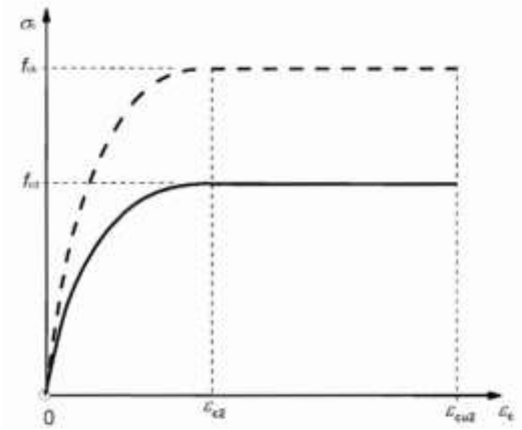

Fig. 8: Parabola rectangle diagram adopted for concrete verification

Ultimate concrete limit states deformation for structure calculation are:

$$\varepsilon_{c2} = 0.2\%; \varepsilon_{cu2} = 0.35\% \quad (4)$$

Table 5 shows exposure class determination according Eurocode standards, [18], [21].

Table 5. Determination of exposure class

Class designation	Description of the environment	Informative examples where exposure classes may occur
2 Corrosion induced by carbonation		
XC3 (top of the slab)	Moderate humidity	Concrete inside buildings with moderate or high air humidity
XC4 (bottom of the slab)	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure class XC2

$c_{min,b}$ is the minimum cover due to because the bond requirement is based on EN 1992-1-1:2004, [20], [21]. The minimum cover values on the top and bottom face slab due to bond requirement, environmental conditions, additive safety elements, reduction of cover for use of stainless steel, and additional protection are taken as below:

The top and bottom cover face slab values calculations are shown in Table 6.

Table 6. Top and bottom face slab values

Cover slab values				
Cover (mm)	$c_{min,b}$	$c_{min,dur}$	Δc_{dev}	c_{nom}
The top face of the slab	20	20	10	30
The bottom face of the slab	25	25	10	35

Moving load LM1 for highway bridges according to Traffic Eurocode loads used for structure analysis is taken as shown in Figure 9, [22].

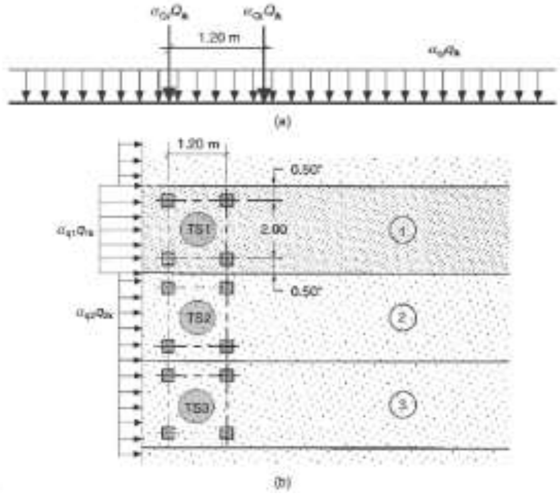

Fig. 9: Load Model No. 1: (a) Application of TS and UDL along the longitudinal axis; (b) Application of LM1 on the notional lanes

Plate stress compression analysis according to the Eurocode standard is shown in Figure 10, [23]

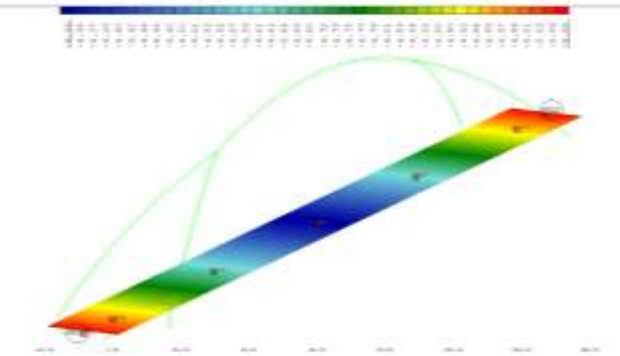

Fig. 10: Plate stress before initial prestress

6 Conclusions

This paper aims to provide a historical investigation of bridge requirements designed with KTP Albanian code and Eurocode requirements. It describes a case study analogy of "Kukësi" bridges, the first one designed and constructed with prior technical code and the second with EN standard.

The use of mechanical material properties and traffic load values application with prior and nowadays codes are presented.

The bridge structure analysis progress is described from historical and technical points of view. This study revealed the use of the low concrete and steel grade class in the old bridges designed with KTP codes, while higher values of concrete and steel grade classes are used for the construction of currently designed bridges.

The length of the main span of the old bridge is about 80 m length, comparing the 270 m span length of the new bridge, which has approximately three times longer span than the first one, as a result of new technological and material progress.

The difference is also observed in the use of traffic load values with KTP and Eurocode standard structure analysis, increasing carrying capacity.

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Conflict of Interest

The authors have no conflicts of interest to declare.