CONNECTION BETWEEN SUPERSTRUCTURE AND SUBSTRUCTURE CONCRETE BRIDGES WITH ASPECT SEISMIC ISOLATION OF CONSTRUCTION

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Summary: *This paper presents the basic principles seismic isolation of concrete bridges using different types connections between superstructure and substructure of construction. In the particular case of the bridge over river Dičina on the section Takovo – Preljina of highway E-763 Belgrade - Požega modeled cases with rigid and hinge connection, and case with elastomeric bearings. Analised influence of the type connection on improving seismic isolation of construction as well as the impact changes the stiffness of elastomeric bearings on the resulting seismic forces. In the conclusions were presented basic observations conducted analysis could be applied at the calculation similar bridges of this type in seismic active areas.*

Keywords: *concrete bridge, connection between superstructure and substructure, elastomeric bearings, seismic resistance, seismic isolation.*

1. INTRODUCTION

As a result of dynamic load, construction of bridges are functioning as 3D systems due to the phenomenon of interaction between their elements. However, the interaction between superstructure and substructure is a major phenomenon to be analyzed [1]. Type connection between superstructure and substructure greatly affects on the size and distribution of seismic forces. Also, the connection between superstructure and substructure of bridge construction directly affects on the stiffness the overall system, and dynamic characteristics of system.
This paper analyzes the impact of the type connection between superstructure and substructure bridge construction and changes the stiffness of elastomeric bearings via parameters height of bearing and shear module on the results of seismic analysis. As each bridge construction has certain specifics, it is not always possible to draw conclusions that are fully applicable to all bridges, and therefore the problem of seismic analysis should be considered separately according to the particular type of bridge construction.

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2. CHARACTERISTICS OF THE BRIDGE OVER RIVER DIČINA

In the particular case of the bridge over river Dičina on the section Takovo - Preljina of highway E-763 Belgrade - Požega analyzed the influence of the type connection between superstructure and substructure bridge construction, as wll as the impact changes the stiffness of elastomeric bearings on the resulting seismic forces. Basic characteristics of the bridge are shown in Figure 1.

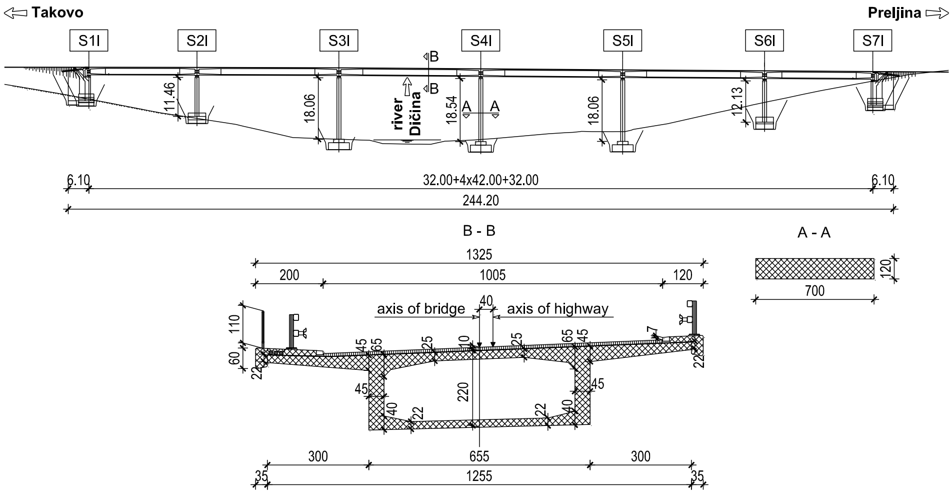

Figure 1. The layout of the bridge over river Dičina with cross sections superstructure and middle piers

Dispositional, bridge construction has a total length of 244.20 m and together with wing walls is one dilatation unity. The construction consists of six spans size 32.00 m + 4 x 42.00 m + 32.00 m with a relatively high piers to 20.00 m. Superstructure is made of reinforced concrete, prestressed continuous beam, supported over elastomeric bearings on piers. The main girder is a box cross-section height of 220 cm and constant in all fields. Bridge deck is constant width 1255 cm and variable thickness from 25 cm to 48 cm. The lower plate of main girder is also a constant width of 600 cm and variable thickness from 22 cm to 45 cm. Above middle piers are provided transverse stiffeners (diaphragm), thickness of 120 cm. The console of pedestrian paths is variable thickness from 22 cm to 45 cm. The piers are rectangular cross-section edges 700 x 120 cm, different height.

The connection between superstructure and substructure realised via elastomeric bearings (NAL), which on the middle piers have a capacity of vertical force 7500 kN at places fixed supports and 7000 kN at places moving supports. On the piers S3l, S4l, S5l are fixed bearings (NAL-f), combined with laterally movable bearings (NAL-b), while on the piers S2l and S6l are longitudinally movable bearings (NAL-b), combined with in all directions moving bearings (NAL-p-1). On the abutment are also NAL bearings which have a capacity vertical force of 3500 kN, and to allow longitudinal displacement of ± 115 mm. The exact arrangement of NAL bearings is shown in Figure 2 [2].

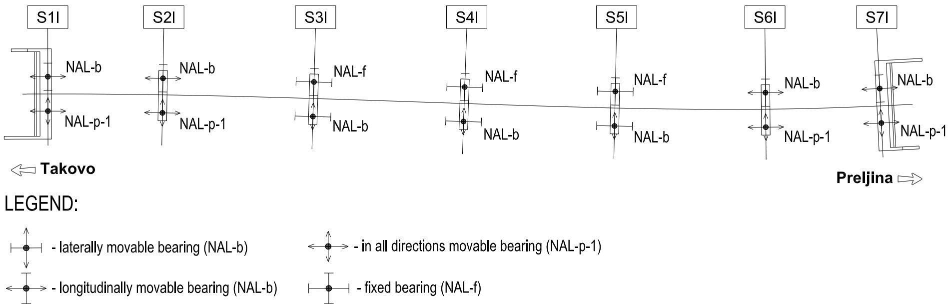

Figure 2. Arrangement of elastomeric bearings (NAL) at the bridge over river Dičina

3. CALCULATION MODELS OF THE BRIDGE OVER RIVER DIČINA

For calculation seismic influence of the bridge over river Dičina were made three calculation models. For all cases connection between superstructure and substructure analyzed 3D systems construction of the bridge with appropriately material and geometric characteristics. The superstructure modeled as 3D system appropriately rigidity with transverse stiffeners (diaphragms), according to the adopted assumptions abutments were treated as fixed supports, while all other piers completely fixed in the foundations.
In the third model elastomeric bearings were modeled as a stick elements with appropriately stiffness according to literature [3]. Calculation of seismic influence is conducted according to the EC8 [4, 5], using multimodal spectral analysis in software package Sofistik.

4. USE OF ELASTOMERIC BEARINGS ON BRIDGES

Elastomeric bearings allow construction responds to dynamic load. Through them part of the construction can dynamically be switched off - isolated. This possibility is very important when a bridge construction should be isolated from the seismic influence, allowing to submit predicted earthquake in elastic state without damage.

Figure 3. Deformation of the elastomeric bearings (NAL) due to vertical force, horizontal force and bending moment

In Figure 3 are shown three conventional forms of deformation NAL bearings due to vertical force, horizontal force and bending moment. Compared to other types of bearings, with NAL bearings can be achieved significant savings, especially because of the simple embedding and cheap maintenance. NAL bearings for bridges are applied in order to reduce the seismic response of horizontal seismic forces. Reducing the seismic influence use of NAL bearings is achieved by increasing the own oscillation period of the bridge construction, ie reducing the force while increasing deformation. Use of NAL bearings is acceptable at bridge construction in seismically active areas, where can be used as a passive isolators of construction.

5. ANALYSIS OF RESULTING SEISMIC FORCES

Analysed three types of connection between superstructure and substructure bridge construction on the size and distribution forces of seismic influence. For the first two cases of rigid and hinge connection are made 3D models which are above the abutments adopted point supports, which allow longitudinal and laterally displacement relative to the axis of bridge. For the third model with NAL bearings on all piers including abutments are modeled per two NAL bearings whose exact arrangement and type shown in Figure 2 and basic characteristics in Table 1. Dimensioning bearings was conducted for applicable vertical and horizontal loads, by satisfying criteria of capacity and stability bearings.

Table 1. Characteristics of elastomeric bearings (NAL) at the bridge over river Dičina

Abutment/ Pier	Type of bearing	Capacity [kN]	Dimensions [mm]	Height [mm]
S1l, S7l	NAL-b	3500	Ø550	126
	NAL-p-1	3500	Ø550	126
S2l, S6l	NAL-b	7000	Ø750	135
	NAL-p-1	7000	Ø750	135
S3l, S4l, S5l	NAL-f	7500	Ø800	150
	NAL - b	7500	Ø800	150

Results of calculation seismic influence for cross-section at the base middle pier bridge are shown in Table 2, adopted shear module of elastomer is G = 1.50 MPa.

Table 2. Influence of type connection between superstructure and substructure on oscillation period of construction and resulting seismic forces

Connection type	T [s]	F_x [kN]	M_x [kNm]	F_y [kN]	M_y [kNm]	F_z [kN]	M_z [kNm]
Rigid	1.75	2.89	67.35	1493.78	15786.55	231.77	34996.73
Hinge	1.94	2.54	74.22	1677.57	16127.13	201.99	0
Elastomeric bearings	2.17	2.13	65.23	1324.79	13564.23	353.21	5683.56

Based on the results in Table 2 can be seen that the rigid connection of superstructure and substructure has the shortest oscillation period and the largest seismic influence. Unlike the rigid connection, use of elastomeric bearings significantly reduces stiffness of constructure and extends oscillation period with reduces the seismic influence. The hinge connection according to the results obtained is in the range between the rigid connection and connection with elastomeric bearings.
Regarding displacement capacity of the system, it is the largest in the case of elastomeric bearings, and smallest in the case of a rigid connection between superstructure and substructure. Use of elastomeric bearings provide a minimum horizontal and something larger vertical resultant of seismic forces. Bending moments at the base piers are the smallest in the use of elastomeric bearings.

6. INFLUENCE OF HEIGHT ELASTOMERIC BEARINGS ON THE CALCULATION RESULTS

Analyzed two cases change in height adopted elastomeric bearings relative to Table 1:

I. increasing height of elastomeric bearings above the piers S2l and S6l to 150 mm,
II. increasing height of elastomeric bearings above all piers to 150 mm.

The calculation results for the shear module G = 1.50 MPa are shown in Table 3 for cases I and II, relating to the increasing height of elastomeric bearings.

Table 3. Influence of height elastomeric bearings on oscillation period of construction and resulting seismic forces

Case	T [s]	F_x [kN]	M_x [kNm]	F_y [kN]	M_y [kNm]	F_z [kN]	M_z [kNm]
I	2.34	1.79	54.27	1199.58	12246.32	281.32	4896.32
II	2.57	1.32	49.74	1003.52	11793.11	264.65	4569.32

Increasing height of elastomeric bearings impact on the reduction their stiffness and stiffness of the whole system, which has the effect reducing the seismic forces. Considering the fact that the seismic forces are reducing with increasing height of elastomeric bearings, in some cases it may be useful to increase the height of the bearings above some piers. This is recommended when need to reduce the seismic forces in the most stressed piers, ie when need to make redistribution of seismic influence.

7. INFLUENCE OF SHEAR MODULE ELASTOMERIC BEARINGS ON THE CALCULATION RESULTS

Analyzed impact of change shear module elastomeric bearings on the calculation results of seismic influence. Shear module is changing in the range of 1.00 - 2.00 MPa as usually stated in the manufacturer's brochures of elastomeric bearings. Some calculation results are shown in Table 4.

Table 4. Influence of shear module elastomeric bearings on oscillation period of construction and resulting seismic forces

Oscillation period/ Resulting forces	G [MPa]				
	1.00	1.25	1.50	1.75	2.00
T[s]	2.53	2.35	2.17	1.99	1.80
F_x [kN]	1.73	1.93	2.13	2.45	2.76
M_x [kNm]	49.86	57.55	65.23	73.79	82.35
F_y [kN]	1056.11	1190.45	1324.79	1546.67	1768.54
M_y [kNm]	12593.21	13078.72	13564.23	14776.35	15988.46
F_z [kN]	276.54	314.88	353.21	382.42	411.63
M_z [kNm]	4876.21	5279.89	5683.56	6006.27	6328.97

Based on the results in Table 4, choice value of shear module elastomeric bearings is significantly affected on the size and distribution of seismic forces. When increasing shear module, reduces the calculation displacement of system and increases the seismic forces. This implies that the calculation should be conducted with a probable lower and upper expected value of shear module (the first to obtain the maximum displacement capacity and the second to obtain the maximum resulting forces).

8. CONCLUSION

Based on the conducted analysis of seismic calculation the bridge over river Dičina on the section Takovo - Preljina of highway E-763 Belgrade - Požega, can be drawn the following conclusions, which can be applied in the design and calculation similar bridges of this type in seismically active areas:

- The reduction of seismic forces with a simultaneous increase displacement capacity of the system can be achieved by modeling the connections reduced stiffness between superstucture and substructure of construction.
- Modeling rigid connections between superstructure and substructure can be achieved something larger bending moments in the piers of the seismic influence compared to conventional hinge connections.
- The use of elastomeric bearings important impact on reducing stiffness of of the whole system and the significant increase displacement capacity of construction, which is accompanied by a reduction influence of seismic forces.
- In certain situations can be justified increasing the height of some elastomeric bearings to reduce seismic forces, ie reduction material in some piers and foundations of the bridge construction.
- Appropriate selection the value of shear module elastomeric bearings is very important because it also impact on the results of seismic calculation. Recommended taking lower expected value for the calculation of displacement capacity and upper expected value for the calculation of resulting forces.

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VEZA DONJEG I GORNJEG STROJA BETONSKIH MOSTOVA SA ASPEKTA SEIZMIČKE IZOLACIJE KONSTRUKCIJE

Rezime: *U radu su predstavljeni osnovni principi seizmičke izolacije betonskih mostova primenom različitih tipova veza donjeg i gornjeg stroja konstrukcije. Na konkretnom primeru mosta preko reke Dičine na deonici Takovo – Preljina autoputa E-763 Beograd – Požega modelirani su slučajevi sa krutom, odnosno zglobnom vezom, kao i slučaj sa elastomernim ležištima. Analiziran je uticaj tipa veze na poboljšanje seizmičke izolacije konstrukcije kao i uticaj promene krutosti elastomernih ležišta na rezultujuće seizmičke sile. U zaključcima su izneta osnovna zapažanja sprovedene analize koja se pored predmetne mostovske konstrukcije mogu primeniti i pri proračunu sličnih mostova ovog tipa u seizmički aktivnim područjima.*

Ključne reči: *betonski most, veza donjeg i gornjeg stroja, elastomerna ležišta, seizmičke sile, seizmička izolacija.*