Bulletin of the *Transilvania* University of Braşov • Vol. 10 (59) Special Issue No. 1 - 2017
Series I: Engineering Sciences

PRESENTATION OF SHORT SPAN REINFORCED CONCRETE BRIDGES

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Abstract: *This paper presents the results of the analysis of reinforced concrete bridges with span ranging from 8 to 12 m. Bridges of this type are usually built on local roads over various obstacles. An analysis of the carrying capacity and usability of the deck slab was performed and a review of the results was given. The required quantity of reinforcement depending on the bridge span was analyzed. All presented bridges were built in central Serbia in the period 2015-2017. The intention of the authors is to show the results of computational models through real constructions.*

Key words: *Bridges, reinforced concrete, short span.*

1. Introduction

Short span bridges (up to 12m) are usually built on regional and local roads over the road gaps, the channels, the streams and creeks, etc., Fig. 1.

Fig. 1. *Local road "bridge"*

The road deck is usually built as a thick slab made out of reinforced concrete with height 1/15÷1/20 of main span. For larger span ranges, slab can be made hollowed for less weight. The plate is directly attached to the end pillars, and the dilatations and the transition plates are not necessary or built. Deck slab and columns are integral bridge parts. The end pillars usually rely on the single foundations, while in the case of a ground with a lower carrying capacity, the foundation on the piles is made. The main advantages of this type of bridges are: fast, easy and simple erection, as well as low maintenance

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costs. Often, due to overload or inadequate maintenance, existing bridges short span are damaged or deteriorated [8]. On that occasion, rehabilitation and reconstruction is necessary Fig. 2. In many cases due to the bridges short span it is often more economical to build a new bridge [6-7].

Fig. 2. *Neglected town bridge*

2. Analysis

Bridges of this type are usually made of reinforced concrete with compressive strength higher than 30 MPa and reinforced with steel bars of strength class of min 500MPa with the class B ductility.

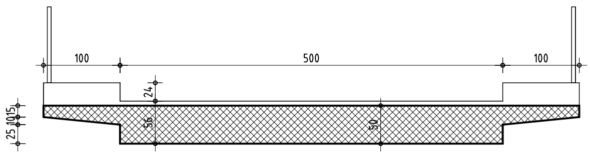

Fig. 3. *Bridge cross section*

The typical cross-section of the deck plate is shown on Fig. 3. In addition to the traffic lanes, consoles for pedestrian lane and passageway for installations are also visible.

A longitudinal cross-section of a typical slab bridge is shown on Fig. 4.

In this paper, the analysis of bridges for several ranges and foundation conditions was performed. Analyzed spams are L=8, 9, 10 and 12 m, while end pillars foundation was done on a single slab or on a three 900 mm diameter bored piles.

A 3D calculation model of whole bridge was developed with plane finite elements. Calculation model is presented on Fig. 5.

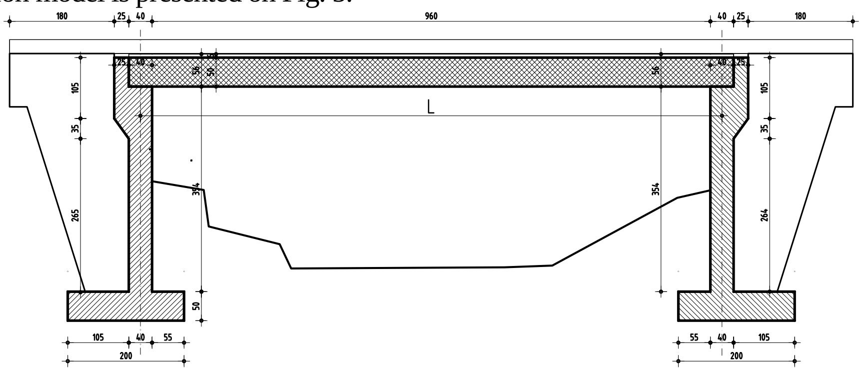

Fig. 4. *Bridge longitudinal section*

All relevant types of loads were taken into account in a single model. Loads included: bridge self-weight, permanent loads from pavement, installation and equipment, ground active pressure, traffic loads included forces from vehicle breaking on the bridge. For the traffic load of bridges on local roads, a 30 tons type vehicle was adopted, with its appropriate concentrated and distributed loads. Influences in road deck, or bridge, are determined in the case of moving vehicles traveling along the curb strip with a calculation step of 0.5 m.

Loads included also constant temperature variation in axis of slab, temperature gradient on the slab height. Also seismic loads in two orthogonal direction were considered. Wind loads on these type of bridges were not considered. Connections on bridge elements were considered as rigid. Only connection between slab and end pillars was modeled with moment end releases. In this way bridge plate can be analyzed as simple beam and vertical displacement of foundation does not have any influence forces in slab.

The ground modeling was based on the Winkler elastic model with real geotechnical characteristics obtained from in-situ soil testing.

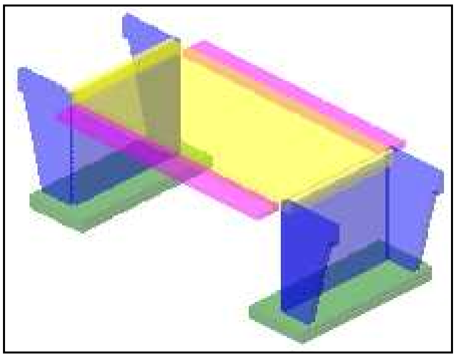

Fig. 5. *Calculation model*

3. Calculation Results

Due to the limited pages of this paper, only the results of the analysis of the bridges slabs are shown. The dimensioning of the slab was carried out according to the ultimate limit state, taking into account the load capacity, as well as the state of the cracks and permanent deformations [9]. The strength of concrete was f_{ck}=35 *MPa* and reinforcement had yield strength of f_y=500 *MPa* the determination of the bridge required reinforcement was performed according to Serbian national concrete standard.

Cracks at time $t \to \infty$ have turned out to be the essential condition of dimensioning with limited width of 0.2 *mm*. The thickness of the concrete protective cover is determined for the medium aggressive environment, that is: 5*cm* for parts below the ground and 4 *cm* for parts above ground.

The calculation results are shown in Table 1. For all analyzed bridge spans results include values for: slab thickness (*d*), maximum bending moments from a permanent load (self-weight, installations, bridge equipment, etc.) (*Mg*), traffic loads (*Mp*), required (*Aa*) and adopted reinforcement, and final deflections in the middle of the span (*δ*).

Calculation results Table 1

***L* [*m*]**	**8**	**9**	**10**	**12**
***d* [*m*]**	40	44	50	60
***Mg* [*kNm*]**	120.58	162.00	218.31	349.13
***Mp* [*kNm*]**	176.27	206.17	231.95	262.11
***Aa* [cm^2/m]**	32.70	36.18	37.82	41.04
Adopted reinforcement	Ø25/10	Ø25/10+ Ø16/20	Ø25/10+ Ø18/20	Ø25/10+ Ø20/20
δ [*cm*]	3.7	4.1	5.0	5.3

It is noticeable that the all presented parameters depends on the bridge span. In figure 6 a diagram of the required quantity of reinforcement depending on the bridge span is shown. Basic reinforcement for all presented bridges was the same. A 25 mm diameter rebar on 10 cm distance was adopted. In some bridges additional reinforcement bars were needed. Those rebar's was added to every other Ø25 bar.

Cracks and deflections were determined for two time states. Elastic state at time t=0, or just after all applied loads and elastic-plastic state at time $t \rightarrow \infty$, which includes all rheological concrete time dependent processes (creep and shrinkage).

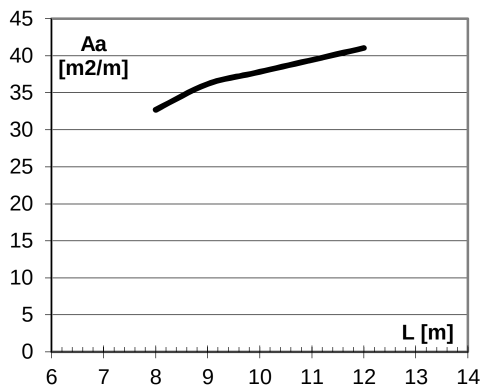

Fig. 6. *Reinforcement - bridge span dependence*

Different foundation conditions did not have any significant impact on the carriage of bridge slab. These was direct consequence of slab-pier connection modelling.

4. Examples of Built Bridges

All analysed bridges were built in the period 2015-2017. in central Serbia in the municipality of Mionica [1-5]. A more than 10 bridges of this type have been built in that time by the first two authors.

The following photos show the stages of the construction of several bridges.

Figure 7 and 8 shows excavation for bridge slab foundations and end piers formwork and concreting. At the back of the Figure 7, a temporary road over embankment can be seen.

Back of the finished end column is presented on Figure 9. It also shows slab's anchor reinforcement and embankment side walls.

Fig. 7. *Bridge foundations*

Fig. 8. *End column concreting*

Fig. 9. *Back of the column*

Figure 10 shows a bridge slab wooden formwork. Steel trusses placed across water obstacle were used as supports for formwork.

Fig. 10. *Bridge slab formwork*

Figure 11 and 12 shows placing the deck slab reinforcement bars and finished rebar ready for concreting

Fig. 11. *Slab reinforcement*

Fig. 12. *Slab reinforcement before concreting*

Figure 13 and 14 shows two finished bridges. These bridges, with 8 and 9 m spans, were built over irrigation canal and town stream. One of the most important tasks when building short span bridges is the construction of concrete and rock canals bottom and sidewalls. In that way water can not create future problem with bridge foundations. These concrete and rock walls can be seen on abovementioned figures.

Fig. 13. *Finished bridge – 8 m*

Fig. 14. *Finished bridge – 9 m*

5. Conclusions

Short span bridges are especially suitable for building on local roads over smaller obstacles. Usually they are made of reinforced concrete as a flat thick slab directly supported by end pillars. From the results presented in this paper it can be concluded that the correct modeling is easy and simple. As one of the major condition for dimensioning of bridge deck slab was the state of cracks in concrete.

All analyzed bridges were built in reality.

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