

Interaction between Engineering Structures and Environment, Illustrated on the Examples of Bridges in Montenegro

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Abstract: The basic goal of this paper is to point out the importance of design shaping as well as the key parameter of the great interaction between the structure and natural environment. However, experiences confirm the fact that the most successful structures, the bridges also, have not got that attribute because of their grandiosity but per their great integration in the nature that is environment. Beside the basic function, that is the usage to man, their integrations in the environment greatly enrich the ambience. The old stone bridges are mostly well integrated in the natural environment. In the period of large building, it did not take care of the parameters (the bridges of steel, concrete and prestressed concrete), but great attention was paid to records referring to spans and complicated forms. The author thinks it is necessary to take care about integration of all building structures in the environment, especially bridges. As a good example of successful creation, simplicity of form, and especially good integration in the natural surroundings are three bridges from Montenegro, one of them is old stone bridge, others are reinforced-concrete and steel bridges.

Key words: Bridges, design, interaction, environment.

1. Introduction

According to experience, it has been confirmed that the most successful structures, bridges are among which have not earned that attribute only based on their grandiosity, but, mostly, because they are well fitted in the natural environment. The most successful bridges which are considered to be the symbols of the architectural creativity have integrated in themselves the construction, functionality, rationality and visual appearance. In order to meet the above principles, they should lie on the following principles: beauty should lie in the forms of construction, simplicity and not in perplexity, functional clarity and not in overlapping, and clarity of concepts and not in accumulation of different elements.

Building of bridges dates back more than 2,000 years ago. At that time, apart from first wooden bridges,

only stone bridges were built [1]. During the last century and a half, construction of steel, concrete, reinforced concrete, previously stressed and composite bridges have been initiated [2]. Such a progress has been characterized by the usage of new, quality materials and improvement of the construction technology. New materials and technologies have enabled construction of very large spans and lengths and overcoming of huge water or dry obstacles. It does not mean that the old bridges have lost their importance, especially not from an aesthetic point of view. Stone and wooden bridges have been rarely constructed today. The existing old bridges have been usually recovered in order to preserve the construction heritage. Unfortunately, most of the bridges collapsed or have been collapsing.

In order to give an example of the successful construction works, functionality of appearance, and well fitting into the environment, three bridges of

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Montenegro have been chosen—the stone one, the reinforced concrete one and the steel one.

2. The Emperor's Bridge

The stone emperor's bridge is the oldest structure of such kind in Montenegro [3]. It bridges the river bed of the Zeta river within the Nikšić field as well as large part the field which is flooded during the time of high water. It is located at the old major road Podgorica-Nikšić. It was completed in 1984 and built of chiselled stone. It consists of 18 arch openings of 296 m of total length. At the bridge extension, an embankment of 600 m length has been made, with the bridge having two arch openings. The total bridge length is almost one kilometer. It was projected by the skilled engineer of that time (Mr. Josip Slade) from

Zadar while the works of the bridge construction were conducted by an experienced builder (Mr. Miloš Lepetić). The bridge was built by the Montenegrin ruler, prince Nikola. The construction works lasted for less than six months. It was named after the Russian Emperor Aleksandar III who helped construction of the bridge. In gratitude, the prince Nikola proposed the bridge to be named "the bridge of Aleksandar III the Emperor", but the people named it the Emperor's bridge, to make it simpler. The appearance of the bridge is shown in Figs. 1 and 2.

This bridge is considered to be an example of harmonious and well formed stone bridge of great length. The chiselled stone gives it the monumental appearance. It is also an example of well fitting into the space and natural environment.



Fig. 1 The Emperor's bridge (upstream).



Fig. 2 Emperor's bridge (downstream).

3. The Tara Bridge

It bridges one of the most beautiful canyons in Europe—the Tara river canyon, at Pljevlja-Žabljak road [4]. It is the most valuable work of architecture in Montenegro and beyond. The bridge is made of reinforced concrete and built in the period from 1938 to 1940. The bridge was designed by the famous yugoslav constructor—prof. Mijat Trojanović. The bridge gradient is located at the elevation of 808.61 m, the elevation of the average water level of the Tara river is 657 m, so that the bridge height over the canyon is around 150 m.

Dispositionally, the bridge was constructed as: the Tara river canyon was bridged by the arch construction of $l = 116.0$ m span, with the $f = 23.71$ m of arrow (compactness $\frac{l}{f} = \frac{23.71}{116} = 4.89$) with the road over the arch. The access construction was made as an viaduct having four arch openings of $l = 44.08$ m span each and the attached beam structure with two openings of $l = 17$ m span each. The bridge width is 6.5 m (road 5.5 m plus two pedestrian paths of 0.5 m). The appearance of the bridge is shown in

Figs. 3 and 4.

The Tara bridge is a very successful designing solution according to all parameters. First of all, it is perfectly fitted into the natural environment, as it was likely made by nature not the man. Although it was made by the man, it enriches the nature and contributes to its beauty. The Tara river is widely known not only by its beauty but its structure. Beside that, it has been designed according to all modern parameters in relation to bridges designing. It is one of the greatest works of design, thanks to its principles compliance and art design, making it one of the world's top achievements of that time and today.

4. The Little River Bridge

The Little river bridge is a railway bridge over the Little river canyon on Belgrade Bar line [5]. It was constructed as the lattice steel constructn on high concrete pillars. It has five openings of $81.20 + 92.80 + 150.80 + 92.80 + 81.20$ m span and total lenght of 498.80 m. Besides huge spans of the steel construction, this structure peculiarity is great height of the line level line over the Little river canyon amounting over 200 m. Consequently, the height of middle pillars is



Fig. 3 Tara bridge with the frog in the canyon.



Fig. 4 Tara bridge (panorama).

from 50 m to 137.50 m. Slopes of the canyon are very steep with gradient of around 45° . The pillars are designed as hollow, coffered of variable cross section, decreasing from bottom to top, having the 40:1 gradient longitudinally and 30:1 transversally. The bridge was designed by Milivoje Kovačević, an engineer and the contractor of Mostogradnja company from Belgrade. The appearance of the bridge is shown in Figs. 5 and 6.

This bridge was constructed within very difficult and inaccessible site conditions. The designer has

made a constructive solution for such conditions as regards security, rationality and appearance. Apart from the successful solution referring to the steel span construction, the designer has succeeded in forming the high front pillars of the bridge in the right way. Their, height variable cross section is a very elegant and successful solution. The bridge fits the environment by its simplicity with no special details. It deserves to be chosen as an example of well formed steel bridge and its specific purpose.



Fig. 5 Little river bridge (close up).



Fig. 6 Little river bridge (panorama).

5. Conclusion

Besides the constructive safety and rationality, a very important aspect of this bridge refers to its visual appearance and fitting into the natural environment. Unfortunately, this aspect has not always been taken into account appropriately. Recently, designers exaggerate trying to get the “modern” solutions with the exaggerated details and complicated forms. One should, also, have in mind that the beauty lies in simple constructive forms well fitted into the environment.

In order to realize the above, it should require that through the doing of space-plan documents, by the request that solutions of the more important structures are got by International competitions, so it should promote successful and criticize unsuccessful structures in front of professional public [6-8].

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