

## PARTLY DESTROYED STONE BRIDGES WITH LONG-TERM USE

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### ABSTRACT

*Natural stone bridges, few of which survived till today, were scattered all over the mainland of Greece but more especially in the most mountainous part of Greece (Central and Northern Greece). Many old stone bridges in Greece have deteriorated due to the effects of earthquakes, weathering and traffic: some of the traffic they were required to carry was much heavier than the one envisaged when they were built [1]. A limited number was blown up during the second world war or sank in water dams. Some of the multi-arched stone bridges have survived with a partial loss of the bearing structure. After this collapse the need of their service required a rapid repair. The most proper material for this purpose was reinforced concrete although its use is not suitable for a historical structure such as the old stone bridges with an age of some hundred years. However in the most cases of half-destroyed arch bridges the missing part of the stone structure has been replaced by a reinforced concrete one. This kind of repair (partial rebuilt) was common in the first decades of the second half of the 20th century.*

*As examples of such an intervention in the past some stone bridges are presented in this paper. Among them the stone bridge of Karditsa over Kalentzis river in Central Greece (19th century) and the Abdoul Hamid bridge over Kosinthos river in Northern Greece (Thrace).*

### INTRODUCTION

The survived till today historical bridges still stand in fortunate areas bypassed floods, earthquakes and wars of old and modern times. All of these are of considerable age (over one hundred years) and many are masterpieces of the Greek bridge engineering in the past centuries. It must be also mentioned that most of the stone bridges are located in very beautiful mountainous areas.

Unfortunately the most of these structures suffer from lack of maintenance. The abandoning of many bridges since the last 60 years, approximately, when the majority of inhabitants of mountain area moved toward the cities and many of the villages are abandoned, the influence of the climate conditions (windstorms, strong rainfalls and frequent snowfalls during winter) as well, contributed to the aggravation of the state of these structures. Problems created by air-traffic pollution cannot appear because the most of the bridges are located in rural districts and not in industrial areas [2]. Nowadays several of them are not in use as modern bridges for heavy traffic loads replaced their function.

A few number of multi-arched old stone bridges are still in use (or were in use till the first decade of the 21st century) although they were partially destroyed; the remaining part of the original structure was repaired and the damaged one was rebuilt in order to continue to serve the people, by the same or an other kind of function [1], [3], [4]. In the most cases of half-destroyed bridges the missing part of the stone structure has been replaced by a reinforced concrete one. Some decades after these interventions signs of ageing and weathering on both parts of the structure, the original

one and the posterior, are evident and strengthening of the whole bearing system is required. The intervention can be very expensive due to the present of the historical old stone part.

For this reason the future of some of these structures is not clear when they will be no more useful for human needs if the historical character will be not recognised. Besides the year of erection, the long-term use of these bridges in the last decades consists an additional reason for their restoration under consideration of their historical value.

This paper presents two multi-arched bridges with a long-term service after the partial damage of their original structure and its replace by reinforced concrete.

## **KARDITSA BRIDGE**

Karditsa stone bridge was built at the last decades of the 19<sup>th</sup> century. It is located at a distance of 5 km from the town of Karditsa over Kalentzis river. The original structure had three main arches but only the middle of them survived till now. The collapsed arches had been replaced by a reinforced concrete structure in order to ensure further use of the bridge (Fig.1). This intervention at the beginning of the second half of the 20<sup>th</sup> century had been made without any respect to the original stone system presented by one semi-circular arch and two relieving openings on the right and the left of it (over the stone piers). For more than five decades (until the half of the first decade of the 21<sup>st</sup> century) the composite bridge was used for heavy traffic loads in the Karditsa region in Central Greece.

The total length of the original stone bridge is unknown but the one of the structure after its repair with reinforced concrete was 60m approximately (Fig. 2). The width of the stone bearing system is 4.00m. The parapet has a width of 0.30m and a height of 0.50m.

In the stone part of the bridge the cornices are made of curved lime stone, the spandrel masonry of hewn lime stone. From time to time the stone masonry joints were repaired with cement mortar. The signs of weathering and ageing were obvious on both parts (masonry and reinforced concrete) of the bridge.

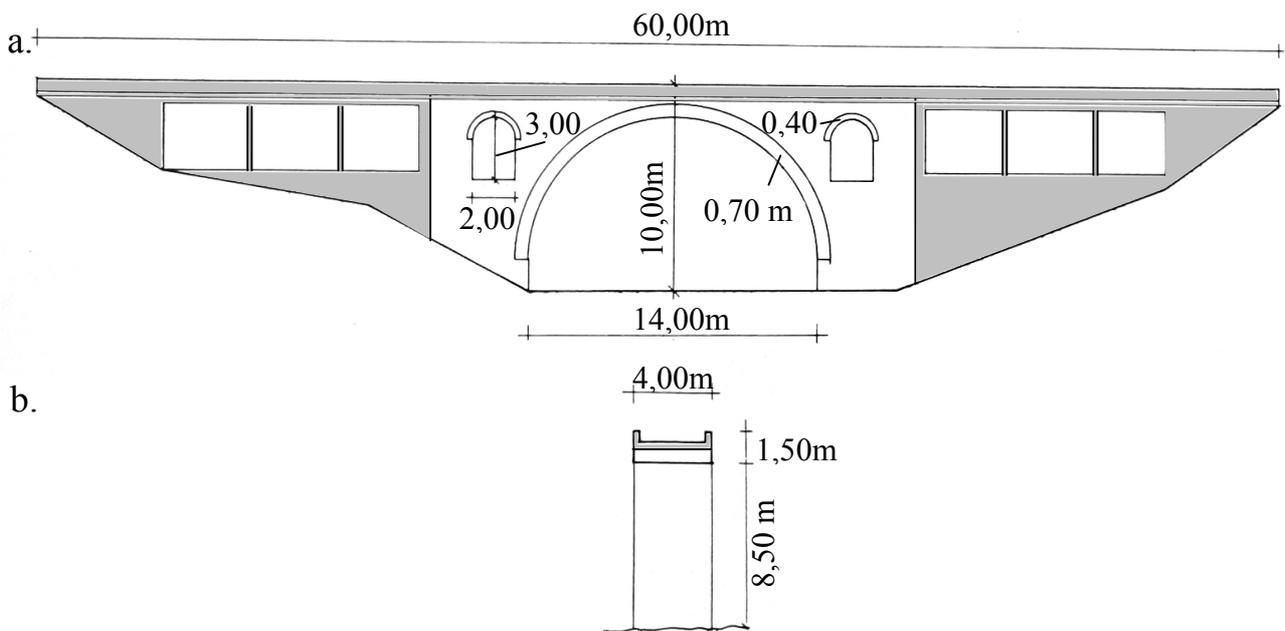
Over the years the local authorities taking into account the increasing traffic in region and the bed river widening decided for the erection of a modern bridge; in 1994 the river overflowed its banks. The first step for this purpose was the demolition of the reinforced concrete part (2007). The former middle arch of the historical bridge (Fig. 3) stays nowadays alone without his long-time "supports". The long-time existed reinforced concrete structure although not proper for the stone old one (mainly for esthetical reasons) ensured the survival of it against earthquakes and floods as the surrounding valley floods often. An analysis of the existing original arched structure[4] according to the current national requirements shows that works for provisional strengthening of the bearing system must be carried out, as soon as possible, in order to prevent a collapse of it caused by an earthquake or a flood.

Interventions for the strengthening of the existing old structure and its promotion in the region on the part of the authorities for the preservation of the old stone bridge must be taken into account under consideration of its historical value. A rebuilding of the missing part of the stone bridge cannot be useful because a modern bridge for heavy traffic will be built near the old one. The location of the bridge as well as its surrounding is suitable for a recreation park with the existing stone part as focal point. However an additional structure (stairs) could help visitors to reach the

upper surface of the stone bridge for a panoramic view over the wide agriculture area and the picturesque villages in the plain.



**Figure 1** Karditsa Bridge at the beginning of the 21th century



**Figure 2** Geometrical data of Karditsa Bridge (a. longitudinal section, b. section at the key)



**Figure 3** The stone part of Karditsa bridge

### **ABDOUL-HAMID BRIDGE**

The second stone bridge presented in this paper is an old structure which was blown up in the World War II (perhaps 1940) and it lost two of the four original arches. At a distance of 3km from the old structure a new bridge was built in order to serve the local traffic. The old bridge was abandoned. A new need enabled the old manufacture to preserve a functional character in a different context. Since some decades the bridge supports the water main of the water supply of the town Xanthi (Eastern Greece). For this function two beams and one pier constructed with reinforced concrete replaced the missing part of the original bearing structure (fig. 4, fig 5).

The bridge is located in a marvelous mountainous region at a distance of 4km from Xanthi, on the road towards the small town Stavroupoli. It spans Kosinthos river and had been built at the beginning of the 20th century during the Turkish occupation. The bridge is named after Sultan Abdoul Hamid.

The original part of the structure is made of curved white lime stone and its total length was 66m approximately [4]. The great width of the superstructure, over 4m, testifies the importance of this road during the last century. Nowadays the existing two of the original four arches and the abutments demonstrate that the involved builders created an excellent feature. As mentioned above, a slender reinforced concrete structure replaced the lost arches and the pier between them in order to serve the water transportation. Unfortunately the primitive concrete structure causes a distortion to the elegant figure of the old damaged bridge. The local authorities built the reinforced concrete part according to the real needs of the communities and ignored the message handed down by the old stone masonry, because of the high cost of rebuilding the missing part with stone. The abandoning

of the mountainous region in the second half of the last century, the weathering and ageing contribute, in the run of time, to the damage of the stone part of the bridge as since a lot of years works for its preservation are not carried out.



**Figure 4** The Abdoul Hamid bridge nowadays (2010)



**Figure 5** The water main in the reinforced concrete part of Abdoul Hamid bridge (2010)

It is remarkable that at a distance of 1km from the Abdoul Hamid bridge there exist two stone arches (and two relieving openings) of a Byzantine multi-arched stone bridge (Fig.6), built in the 16<sup>th</sup> century. Obviously the tortuous mountain road Xanthi-Stavroupoli-Drama was the main artery of communication in this part of Thrace since several hundred years.

The future of the Abdoul-Hamit bridge as well as the Byzantine one is very difficult. Reuse of these bridge structures could suggest new design configurations to service their surrounding area. A repair-preservation of them can be included in a project for the promotion of the whole mountainous region in this almost “unknown” part of eastern Greece. The project can have two targets:

- repair and rebuilt with stone masonry of the damaged part of the Abdoul-Hamit bridge and the existing one of the Byzantine construction
- aesthetic improvement of the surrounding of them and perhaps providing for tourist service in the site.



**Figure 6** Remains of a Byzantine bridge close to Abdoul Hamid bridge nowadays (2010)

## CONCLUSION

The case studies in this paper show that stone bridges, even if partially destroyed and unfortunately repaired in the past due to once real needs, can continue to serve. Nevertheless they are important remainders of the Greek bridge engineering and a future intervention should be carried out according to the present considerations for preservation of historical structures. Several small and large bridges scattered all over the mountainous Central and Northern Greece and they are not inserted in a cultural economic circuit, as some historical buildings in town centers. Local communities should undertake works for their preservation because these old structures are important for the history of construction science and of the territory itself as they can continue their service for real needs without loss of their historical character.

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