Technical and Environmental Aspects of Infrastructure Restoration after Destruction of Bridges in the City of Novi Sad

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Abstract

This paper deals with the riverbed morphological and environmental changes induced by destruction of bridges in the city of Novi Sad. Different aspects of infrastructre restoration are discussed. The problem of gas pipeline restoration is presented in detail.

Key words: Danube river, riverbed morphology, pipeline crossing, environmental restoration

Introduction

In the course of NATO raid on Yugoslavia in 1999, three bridges on the Danube river in the city of Novi Sad were destroyed: the suspension steel Sloboda bridge (km 1257.60), the steel truss Petrovaradin bridge (km 1255), and the prestressed concrete Zezelj bridge (km 1254.17, Fig. 1).

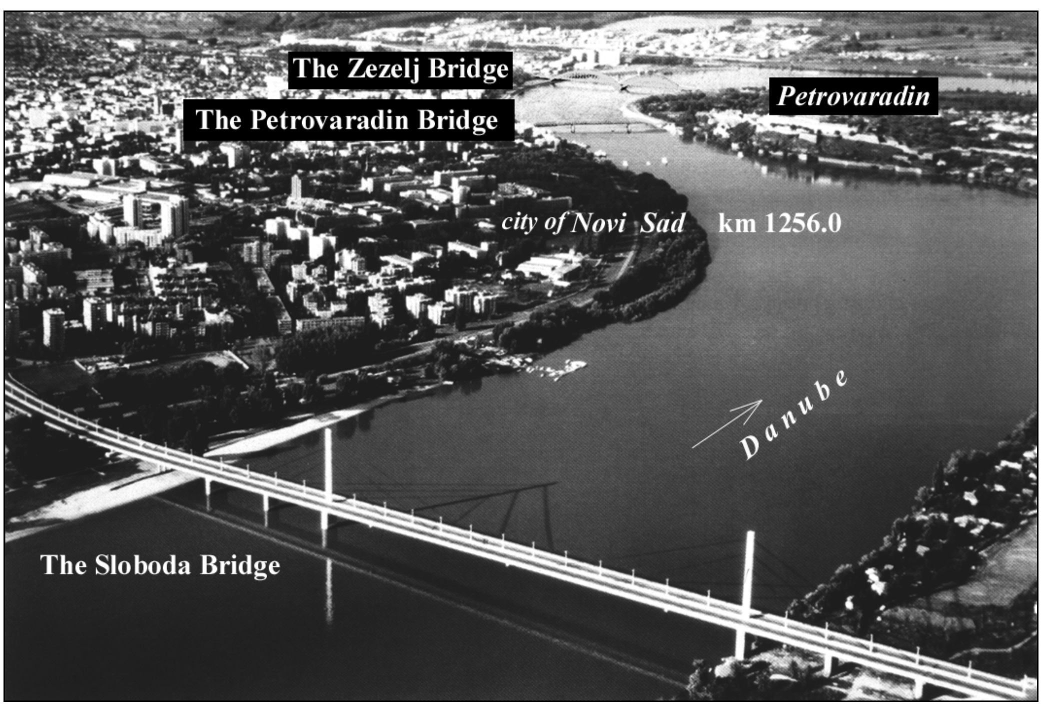

Fig. 1. Layout of bridges in the city of Novi Sad prior to NATO bombing in 1999.

Destruction of the bridges disrupted road and railway traffic, navigation on the Danube international waterway, and water and gas supply through pipes, which were mounted on the bridge structures. Severe sanitary problems were present due to shortage of water, and cutting off the gas pipeline disabled gas supply indispensable for industrial and domestic use.

The bridge debris on the bottom of the Danube river formed large obstacles to the flow, causing severe morphological and environmental changes, which hydraulic engineers have not had a chance to cope with yet.

Scope of restoration activities

The first step in restoration was reconstruction of the vital infrastructure facilities – water supply and gas pipelines. The urgency of the matter, available financial funding, and available materials, as well as the position of the existing installations on the water distribution network and on the main gas pipeline determined the pipeline crossings, their characteristics, and the technology of their launching. New pipes were placed on the bottom of the river immediately downstream from the destroyed Zezelj bridge (Fig. 2), regardless the eventual morphological riverbed changes that could have been neither qualitatively nor quantitatively estimated in short time, since no similar events had happened ever before.

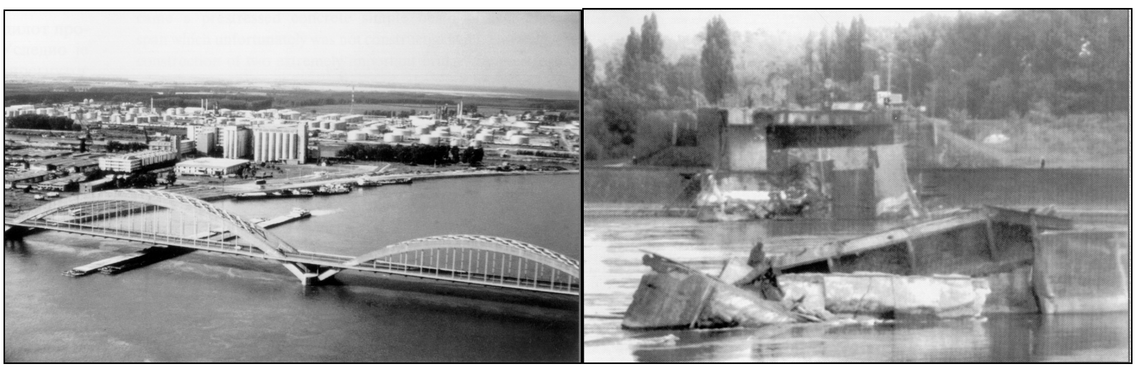

Fig. 2 The Zezelj bridge (km 1254.17) prior to and after destruction on April 26th 1999; its prestressed concrete arch structure had 231 m and 180 m spans founded on three piers.

The second, equally important problem, was, and still is, restoration of the obstructed riverbed, which implies restoration of the hydraulic, sediment, and ice regimes of the river, as well as restoration of the riverine aquatic ecosystem. Cleaning up of the riverbed, together with restoration of hydraulic, sediment, and ice regimes, is imperative for commercial navigation along the international danubian waterway. Protection of the endangered banks and bank revetments is also necessary, complying with environmentally sound solutions.

The complexity of problems regarding safety of the gas pipeline due to the morphological riverbed changes induced by a bottom sill formed of the Zezelj bridge debris, will be presented in the following paragraphs.

Consequences of destruction of the Zezelj bridge

The Zezelj Bridge, a massive, prestressed concrete arch structure founded on three piers, with 231 m and 180 m spans, was destroyed on April 26th 1999. The sunken structure formed a sill on the bottom of the river, inducing intensive turbulence and erosion downstream (Fig. 3).

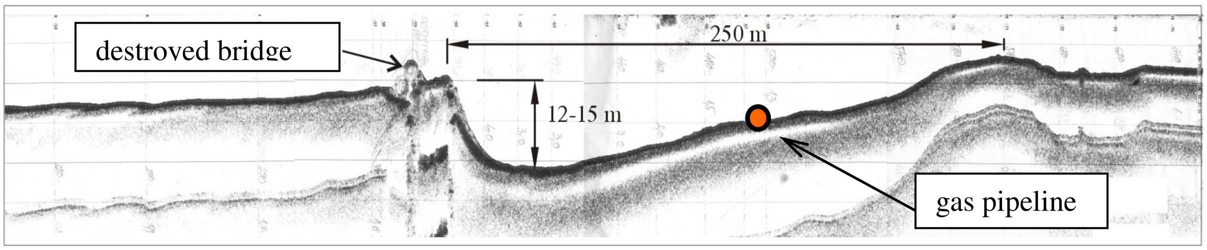

Fig. 3 Longitudinal profile of the riverbed made by sounding device six months after destruction of the Zezelj bridge

The maximal depth of the scour hole is presently about 15 m, and its width about 140 m. Practically all alluvial material (sand and gravel) has been washed out from the deepest part of the hole, and the clay stratum has been reached. The evolution of the scour hole is depicted in Fig. 4.

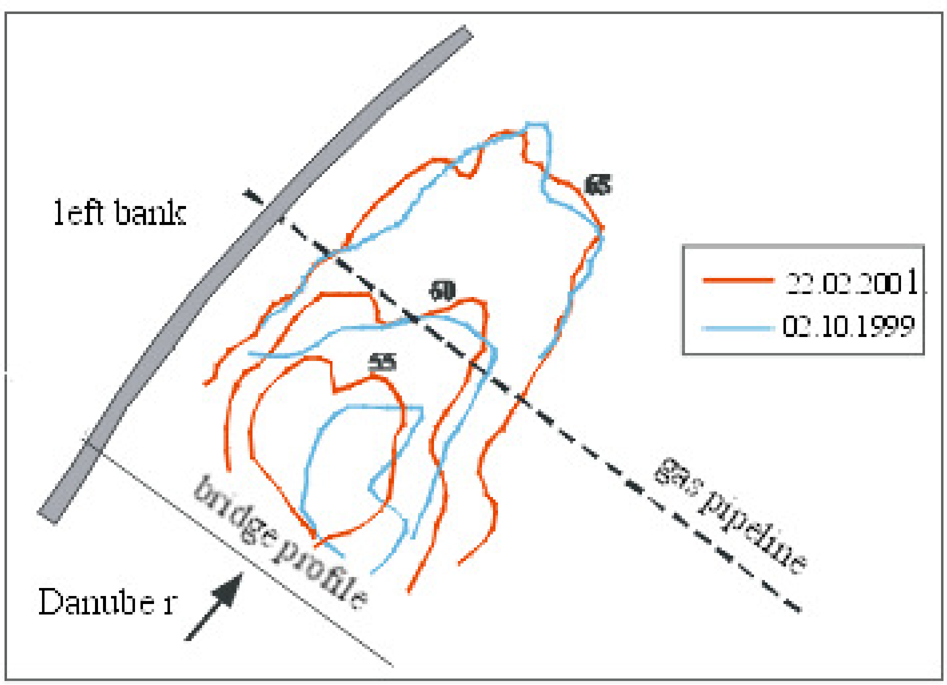

Fig. 4. Lines of equal bed elevation showing changes, which occurred in 16 months

Generally, the scour hole is continuously moving downstream and toward the left bank. Several flood events occurred during this time. It is estimated that about 10000 m^3 of the river bed material has been washed away from the hole in this period. Most of this material (as well as material from minor scour holes formed in the zone of other two destroyed bridges) has been deposited in the downstream sectors of the Danube. It is observed that morphological changes in the city of Novi Sad propagate almost 40 km downstream, where, due to increased sediment loads and insufficient river transport capacity, sand bars developed, flow locally changed its course, and bank instabilities occurred.

In the zone of the sunken structure of the Zezelj bridge, the flow is extremely turbulent, with local velocities of 2.5 m/s under mean discharge rates. This not only hinders navigation and activities on the riverbed rehabilitation, but also has a deteriorating impact on the aquatic ecosystem.

Technical aspects of the problem

By monitoring the zones of pipeline crossings, it was discovered that the process of downstream evolution of the scour hole has left the gas pipeline bare on a length of about 60 m (It is supposed to be safely buried into the river bed). In order to prevent disruption of the gas supply, technical measures were urgently initiated in the summer of 2001, not waiting for the beginning of the European Union financed works on the riverbed rehabilitation of the entire Novi Sad river reach. The technical solution was coped with a number of problems:

(a) How to estimate a financially reasonable scope of works, having in mind that once the removal of the Zezelj bridge debris is started, a completely new flow field will result, demanding for additional works, possibly even for the entire dislocation of the pipeline;
(b) How to propose efficient technical solution for the pipeline restoration;
(c) How to choose adequate construction material, and such building technology, which would not endanger the safety of the exposed pipeline, under high flow depths and velocities.

The problem was solved by constructing a bottom sill made of large stones (35-40 cm in diameter). This stone structure protects the pipeline as shown in Fig. 5. The aforementioned scour hole downstream translation is also evident in this figure. The sill is gradually formed along the unsupported 25 m long segment of the pipeline. Submergence of the stones was strictly controlled, i.e. stones were cautiously placed on the river bottom, ensuring the safety of the pipeline. Morphological changes of the riverbed were continually monitored. Sounding data show positive effects of the executed works.

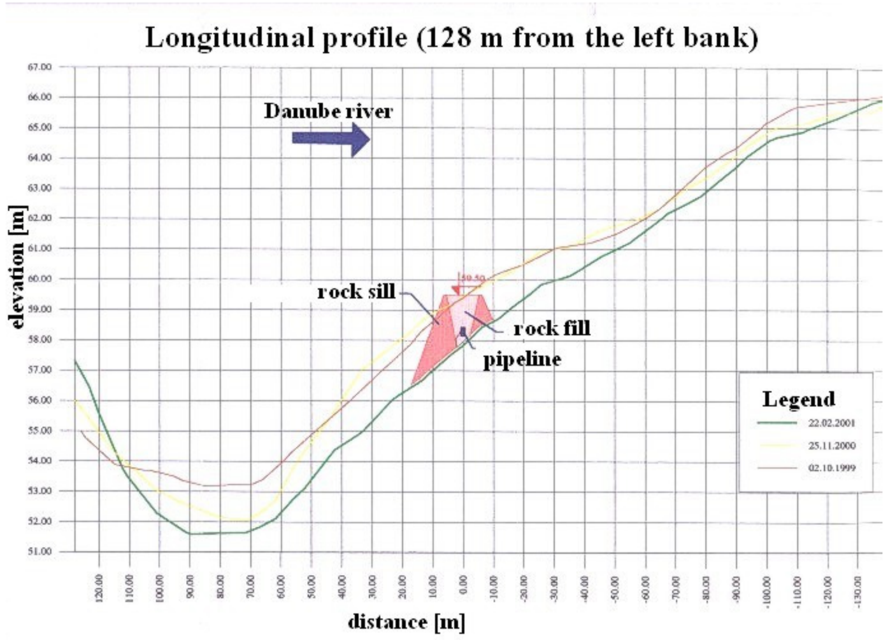

Fig 5. Technical solution for protecting the gas pipeline

Environmental impact

The basic feature of the restoration at present is safe gas supply, and control of further erosion process. The next step in restoration will be removal of the Zezelj bridge debris in order to stabilize the riverbed and enable navigation. Two problems will arise:

(a) Formation of a new flow field with potentially detrimental effects on the safety of the water supply and gas pipelines on the river bottom (away from the completed protection works) and the revetment structures on the river banks;
(b) The bridge construction will be split into fragments, a part of which will be buried into the scour hole. There is a possibility that some of the remaining parts will be taken out of the water and deposited on the banks, in which case environmental aspects of this deposition should be considered.

Conclusions

The problem of the Danube river reach through the city of Novi Sad is a complex one. The scale of the riverbed morphological changes has never been experienced so far. Restoration of the river natural flow regime is prerequisite for all other types of restoration, as shown by the example of the gas pipeline.

References

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