# Reconstruction of more than 100 years old bridges

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## Summary
There is a good chance to save the monument bridges still in use, representing significant technical value and to keep the original structural elements even in the case of road bridges carrying also trams, since tram loading governs compared to road traffic, and these loadings can often be assessed for the past. Also the total weight of vehicles moving in the future can be restricted. These structures can be preserved for the next generations by replacing deck supporting elements, retaining structural elements playing a key role in appearance (main girders, cross-girders), and constructing a modern deck with favourable dynamic characteristics.

**Keywords**: monument bridges, fatigue, stress range spectrum, reconstruction, Gerber-hinge bridge, bridge aesthetics

## 1. Introduction
At the turn of the 19th and 20th centuries, Gerber-hinge bridges were frequently used in large-span river bridges due to the statical and constructional benefits of this structural system. Only a few of these bridges are still in use, which are considered technical historical monuments of high importance, and the majority of them are protected by the authorities as heritage monuments. Today's engineering society is bound to keep them under all circumstances provided that they can sustain the loads acting on them, possibly with reasonable interventions.

The two bridges presented in the lecture are Szabadság Bridge of Budapest, Hungary and Traian Bridge of Arad, Romania. The former one was built in 1896, it bridges the Danube with a total length of 334 m and a middle span of 175 m, and it is distinguished from others by its ratio of spans, structural arrangement and portal formation. Besides the Lánchíd (1849) and Margit Bridge (1873), this bridge is one of the three Danube bridges of Budapest protected as a monument. Traian Bridge was built in 1911, with a length of 184 m and a middle span of 84 m, and though it is smaller, it has also a great technical value.

Regards the bridges older than 100 years by now, it is a fundamental question, under which conditions are they able to sustain the dominant tram loading, and the additional road traffic.

## 2. Reconstruction of the Szabadság Bridge, Budapest, Hungary
Szabadság Bridge represents a unique value among the bridges of Budapest. Many allege that the bridge structure protected as a monument is one of the most beautiful bridges of Gerber-hinge system. Apart from the wing bridge of Margit Bridge, it is the only bridge among the bridges of the Hungarian capital city still retaining its original structure after its destruction in World War II and reconstruction afterwards. Among the Hungarian large-span bridges, this is the first one, where the beauty of steel fully appears in the architectural solutions of the portal and in the fine details of the railings.

The slim and dynamic shape of the bridge, the unique side span / centre span ratio are enabled by the applied structural solutions (counterweights at the abutment, special cross-section design inside


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the Gerber-hinges).

The Szabadság Bridge suffered damages during World War I. In January 1945, the centre span of the bridge was blown up. Since the two side spans were relatively undamaged, this was the first bridge that could be restored. The main trusses of the middle span were remanufactured, while the longitudinal girders had to be replaced from ruins of other bridges. Beyond the numerous injuries on the old remaining elements and the built-in remains of other structures, corrosion added further uncertainties concerning the load-bearing capacity of the bridge.

Calculations on the basis of linear damage accumulation rule and using also numeric simulation performed in the mid-90s showed that longitudinal girders, mainly elements from other bridges, might not be suitable for further use, all other structural elements seemed to be acceptable according to the calculations using also probability considerations.

Two diagonals of the main truss required a specific test. A 15-hour-long stress measurement was performed on the diagonals in question under rush-hour traffic conditions. According to the instrumental test, the effect of road traffic was low compared to the dominant effect of the tram loading causing peak stress values. The measurement proved that the maximum stress change remained below the cut-off limit value in most cases. The testing confirmed the decision to retain the main load-bearing elements of the bridge.

Since during the reconstruction performed in the 90s the closure of the bridge and therefore the general refurbishment of the bridge were not possible, trams had to operate under the continuous control of the structural elements on the bridge, and the traffic was to be stopped in case of an emergency.

Previously postponed works could be performed in 2007 due to the traffic closure required in connection with the construction of Metro Line 4 of Budapest. During the reconstruction, the longitudinal girders of the bridge were remanufactured, the steel structural elements of the bridge were repaired and strengthened, the reinforced concrete deck was reconstructed, the concrete sidewalk was substituted by a steel sidewalk structure to reduce dead weight, all steel structures were repainted, the piers and abutments were repaired, and the tram track was changed to a modern structure with better dynamic properties.

## 3. Reconstruction of the Traian bridge, Arad, Romania

With its length of 185 m and middle span of 85 m, the Traian bridge is a valuable historic example of old bridges over the Maros / Mures river. The structural system of the bridge is similar to that of Szabadság bridge, its 45 m long suspended middle span is supported by Gerber-hinges of rocker-bar design.

The bridge was blown up during World War II. After falling into the riverbed the structure was restored. Several damages were not repaired however.

The damage resulting from corrosion was much more severe than in the case of Szabadság bridge, mainly on the lower chords on the main trusses and at the connections of the cross-beams.

Besides the trams operating on the bridge, the structure was exposed to heavy road traffic as well. When the heavy road traffic was finally diverted, the loading of the bridge significantly decreased, and saving the main load-bearing elements of the bridge in their original forms by means of repairs and strengthening became possible, as well as an overall reconstruction taking into consideration past and potential future tram loadings.

Based on calculations, main girders and cross-beams were repaired and retrofitted, stringers were replaced by newly manufactured girders, and a reinforced concrete deck was built, which is connected to the top flange of the stringers by headed studs, so that together they form a composite deck. The track is supported by a flexible, continuous structure to reduce dynamic effects and noise.