Concise History of Liberty Bridge in Budapest

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Abstracts: The "Fővám tér" (1896), "Ferenc József" (1896-1946), "Szabadság" Liberty Bridge (1946-) was completed in 1896. The bridge was demolished by explosion during the Second World War (1944). On the site of the bridge a temporary bridge was used for a while and in 1946 the bridge was reconstructed. In 1979-80 the deck of the bridge has been replaced. The reconstruction of the main structure was started in 1985, which has been finished successfully in 1986 after several unexpected events. In 1998 some changes has been applied to the deck again, which was followed be a full reconstruction in 2009. Since that time the bridges being an ornament and jewel of Budapest, but also it is a symbol of the Hungarian Capital development to a metropolis.

1. Names and location of the bridge

Names of the bridge:	1894 – 1896 "Fővám-téri" Bridge
	1896 – 1946 "Ferenc József" Bridge
	1946 – "Szabadság" Liberty bridge (Fig. 1-2)
Distance from Sulina:	1645,300 km

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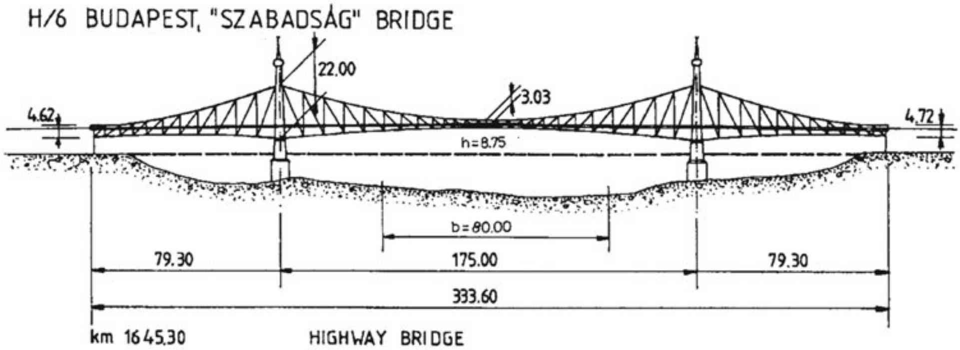

Figure 1: “Szabadság” Liberty Bridge

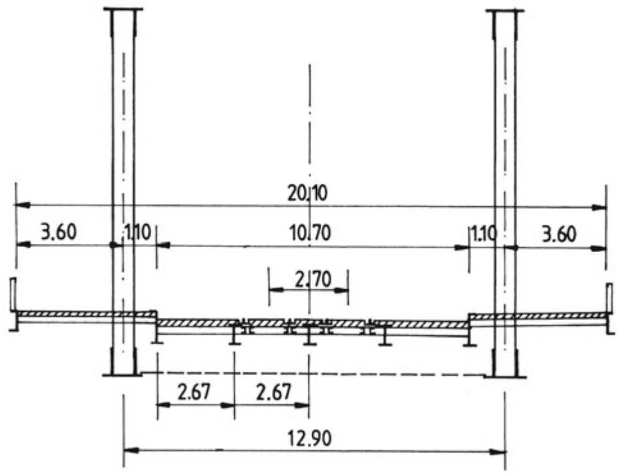

Figure 2: Cross-section of “Szabadság” Liberty Bridge

2. History of bridge design process and erection of structures (1894-1896)

The construction of the “Erzsébet”, Elizabeth and “Szabadság”, Liberty bridges was ordered by Law No. XIV. in 1893 on the occasion of the forthcoming Millennium of Hungary in 1896, and a common tender was held with great success. All together 74 design-plans were presented in the applications, among them 53 for the Elisabeth Bridge, and the balance for the “Szabadság” Bridge. The members of the international jury were bridge engineers of the highest reputation of the time. The Reporter of the jury was Prof. Antal Kherndl, the well-known professor of Technical University in Budapest,. 41 designs were solved with a single-span structure; 15 designs were Hungarian, 16 were American, several were Italian, Austrian, German and French.

Figure 3: “Szabadság” Liberty Bridge and Gellért Hill

The first prize was given to the cable-bridge of Julius Köbler from Germany for the later Elisabeth Bridge; while the second prize winner plan of János Feketeházy and the third prize winner plan of Róbert Totth were prepared for the Liberty Bridge.

The second prize winner plan of János Feketeházy was realized with small modifications. The details of the plan were worked out by István Gállik and József Beke, for the portals, having an architectural importance, were designed by Virgil Nagy, professor of the Technical University, who was the architect specialist of the design team. (Fig. 3) The quality of the shape of the bridge was recognized by many professors [Merthens, 1898]; the end portal and the bridge is considered as one of the most important monuments of the turn of the century.

The **construction started in 1894.** The foundations are iron caissons, made by Gartner and Zsigmondy Company. The erection of the wrought iron superstructure was carried out between July 1895 and August 1896. The ironwork was fabricated and erected by the Factory of the Hungarian Kingdom Railway (MÁVAG), under the direction of Gyula Seefehlner. (Fig. 4)

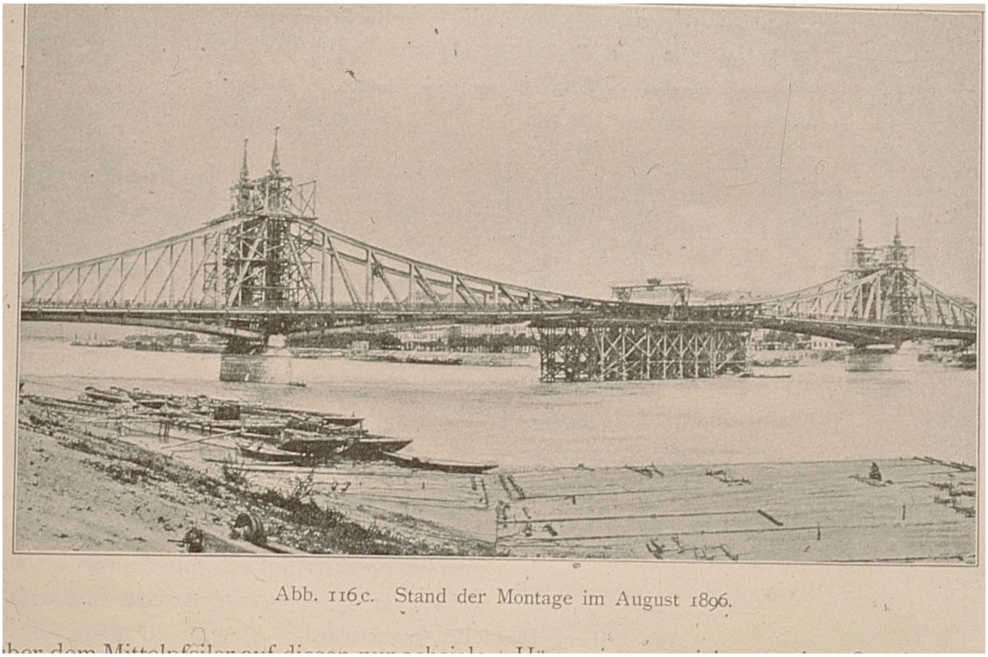

Figure 4: Erection of the part of Gerber (1896)

The **opening of the bridge** took place on October 4th, **1896**, during the Millennium Ceremony in the presence of the Hungarian King and Austrian Emperor Ferenc József, consequently the bridge was called the “Ferenc József” Bridge for decades.

3. During Second World War

The simple supported mid-span and the cantilevers were **blown up in January 1945.** During the construction of a provisory bridge the Buda side span fell down, as the ballast weights at the side support were not removed. (Fig. 5)

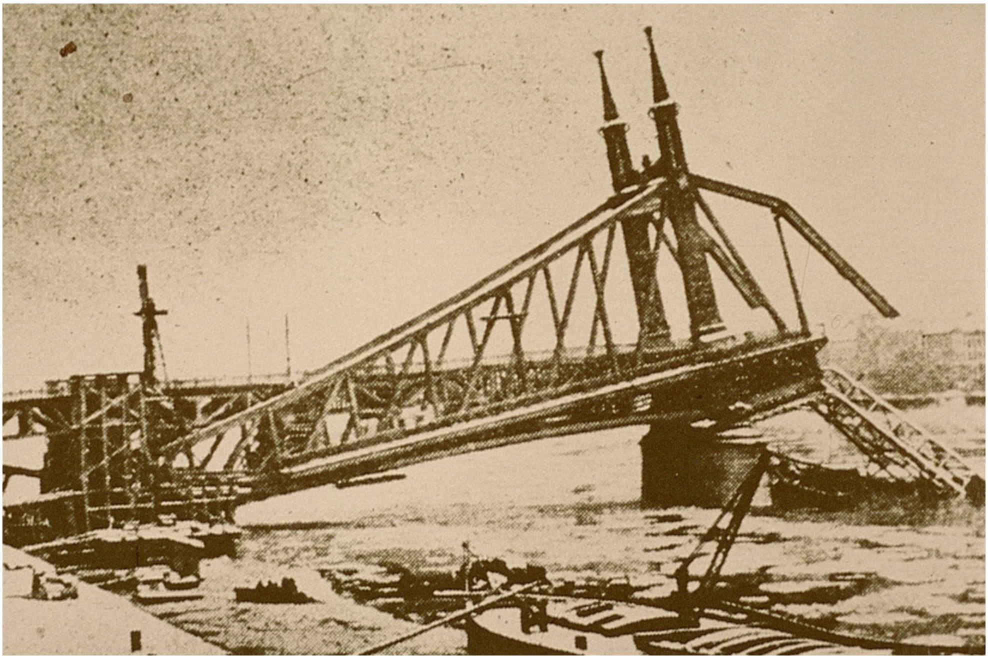

Figure 5: Blown up the Bridge

A **provisory bridge** was built in the mid-span on five barges and on the wrecks of the Buda span from March 15, 1945, but it was drifted by an ice-flow in January 10, 1946 (Fig. 6). Fig. 6 Provisory bridge in January 1946

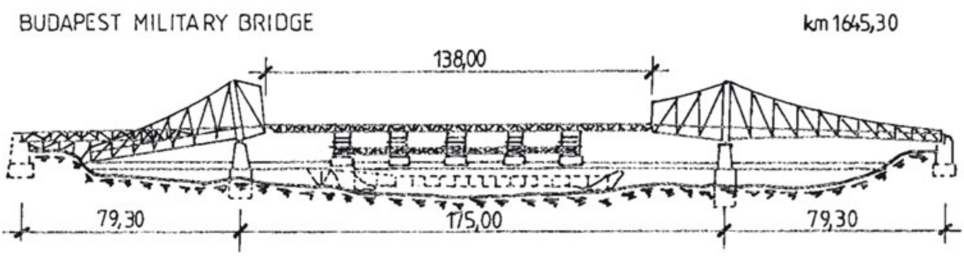

Figure 6: Provisory bridge in January 1946

4. Reconstruction of bridge (1945-1946)

As the bridge was the relatively less damaged one in Budapest, its **reconstruction** was the most realistic. For this, steel materials from the other destroyed bridges were used as well.

4.1 The first stage of the reconstruction

The first stage of the reconstruction was the lifting of the cantilever parts. The main girders of this steel bridge are cantilever type running over three spans (Fig. 7) [Haviár, 1947].

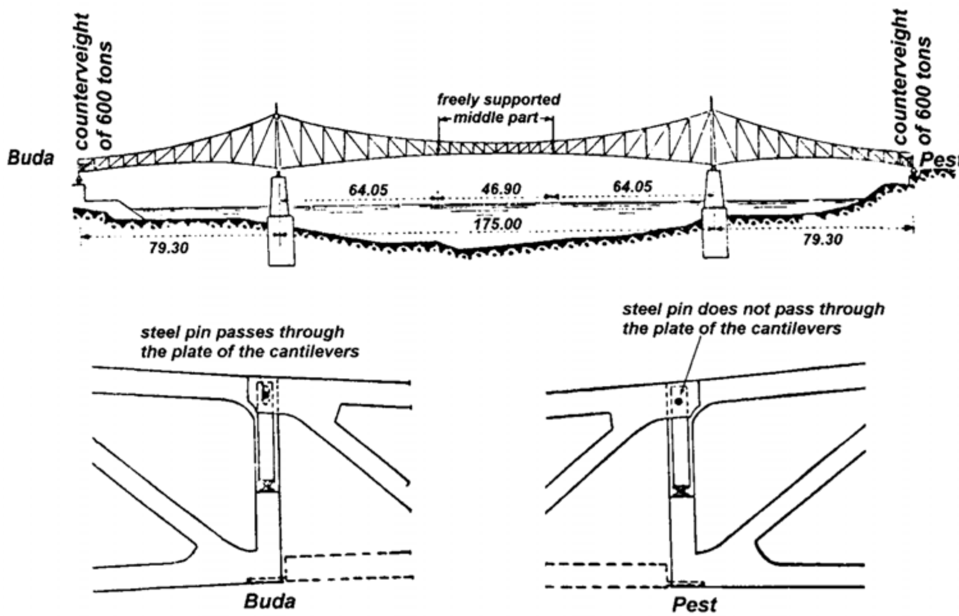

Figure 7: The cantilever type main girders

The reconstruction was carried out based on the original plans. 2250 tons of iron were needed for the reconstruction - representing 38% of the total material. About 550 tons of steel necessary for the less important cross girders were taken from the wrecks of other two Danube bridges, therefore only an amount of 1700 tons had to he supplied by the rolling mills.

The reconstruction of the bridge was executed in three steps:

(a) The first step of the first stage of the work: For raising the 730 tons weight of the anchor arm on the Buda side enormous scaffolding was erected. The uplifting device worked by 16 hydraulic jacks of 100 tons each was placed on the top of the stage. The lifting forces of the jack were transmitted through thrust blocks and through huge suspending rods (bars) made of chain links of the Elisabeth-Bridge. The latter served also as straps for binding the sunken down ends of the main girder.

The bridging scheme planned by Chief-Engineer László Lébényi was as the following.

Two thrust blocks were supported directly by two hydraulic jacks (Fig. 8) and the perforated lifting rods were passed through the slot. The height of lift was altogether 9.30 m and by such 20 cm steps all the work was done within four days.

(b) The second step of the first stage of the work: The wrecks of the 2,5 m long broken part of the right anchor arm were removed and a newly fabricated steel structure was built. The new portion was adjusted from a stage erected under the side span. The uplifted part of the bridge was carried by the above mentioned chain links, while the new bays were being riveted together with the old ones. When all this was done the steel super structure was let down on its final supports by taking out the supporting wedges.

Apart from this 25 m long section the other missing bays of the bridge in a length of about 140 m were erected without any false-work partly because the wrecks of the blown bridge would have hampered the piling and partly because of the great timber shortage.

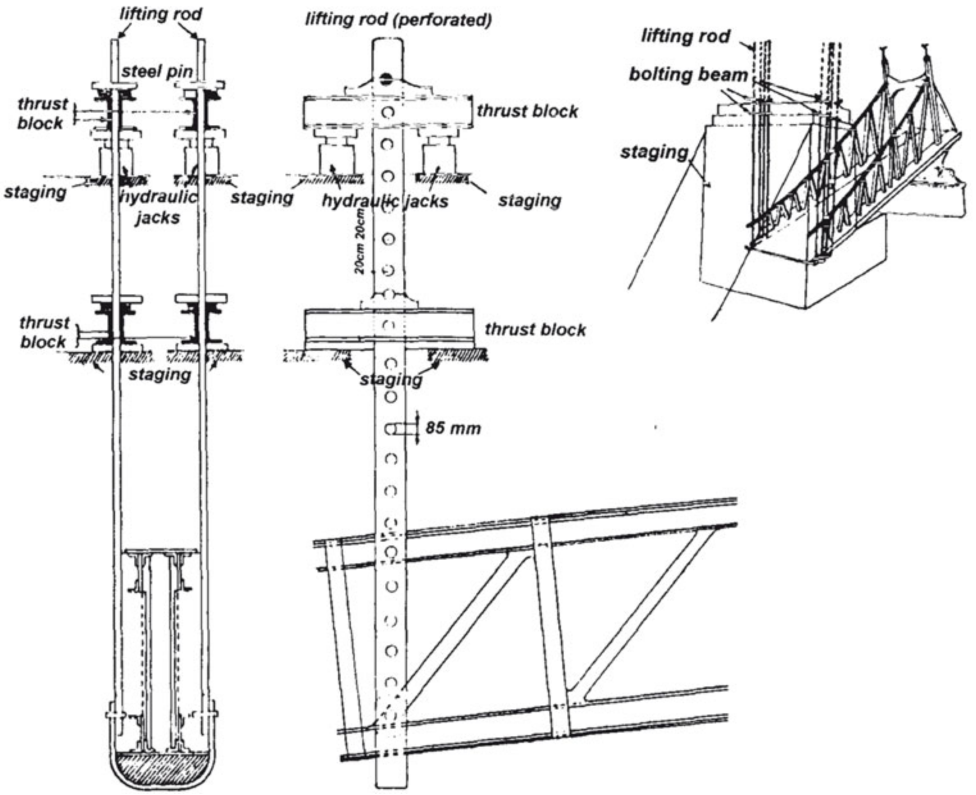

Figure 8: The bridging scheme

The cantilever trusses of 64 m each were built by the cantilever method piece by piece. The main girders of the 46.9 m freely suspended middle span were carried by two floating derricks of 100 t each in the middle of the river and placed directly on the hinges of the projecting ends of the cantilever arms.

The assembling of the cantilevers themselves was done with the aid of a derrick of 5 t moving forward on each end of the existing structure. The lifting of the heavier pieces was accomplished with a floating derrick of 100 t.

The procedure took about four hours for each main girder.

(c) The third step of the first stage of the work was the repair of the bomb-damaged parts of the old iron structure on the bridge itself. With a single exception these works were done without false-work. The damaged vertical struts of the main girder were replaced one by one. At places where the load was greater, a special device was used.

Buckling of the two struts the stresses in the chords computed by Hook's formula exceeded the ultimate tensile strength of 3600 dN/cm^2 of the steel material. Actual stresses, however, exceeded but slightly the yield point, because straining compensated and leveled the increase of the stresses. However, luckily the bridge did not collapse owing to the fact that the stiffness against bending was much greater in the chords than in the lattice work. In this way similarly to a continuous girder the chords transmitted the load over the damaged vertical columns to the other undamaged parts of the bridge. At the final reconstruction of the bridge it was impossible to insert columns which were shorter by 11.2 cm and 6.7 cm respectively because large bending stresses could have remained in the lattice work that in case of live load the structure would have failed due to these excessive stresses. The chords which were bent had to be move apart first. This could be done in two ways:

1. with a direct method by lifting the damaged main girder.
2. with an indirect method by actually pressing the top and the bottom chords apart by the aid of temporary steel struts actuated by hydraulic jacks.

At the reconstruction both methods were resorted to.

The stage needed for lifting was built on 24 wooden piles driven in the river bed at the joints of the main girder marked 7 and 8. (Fig. 9) Beside each buckled strut two temporary steel columns were placed for pressing the chords asunder. On one end of these temporary columns hydraulic jacks were inserted.

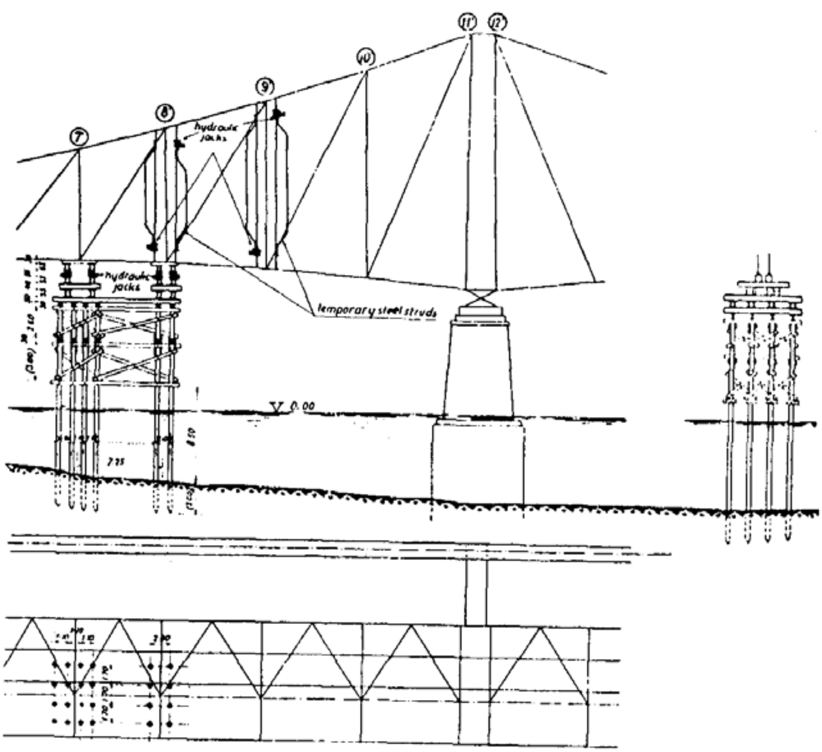

Figure 9: The stage for lifting

4.2 The second stage of the reconstruction

The second stage of the reconstruction was the midspan of the bridge. The midspan had to completely rebuilt, its material was produced in the iron-works of Diósgyőr and Ózd. (Fig. 10) After the reconstruction of the two cantilevers the lift-in operation of the mid-span structure was realized with the floating crane of "József Attila" and "Ady Endre" having a lifting capacity of 100 t each. The total weight of the 46.9 m long main piece was 240 t, therefore this operation needed special care. Some local damages remained on the bridge.

Liberty Bridge was opened 20 August 1946.

After 33 years of service the complete floor system and the suspension system of the counterweights had to be reconstructed in 1979. Further reconstructions were made in 1979-80, when the roadway structure was changed to a composite one.

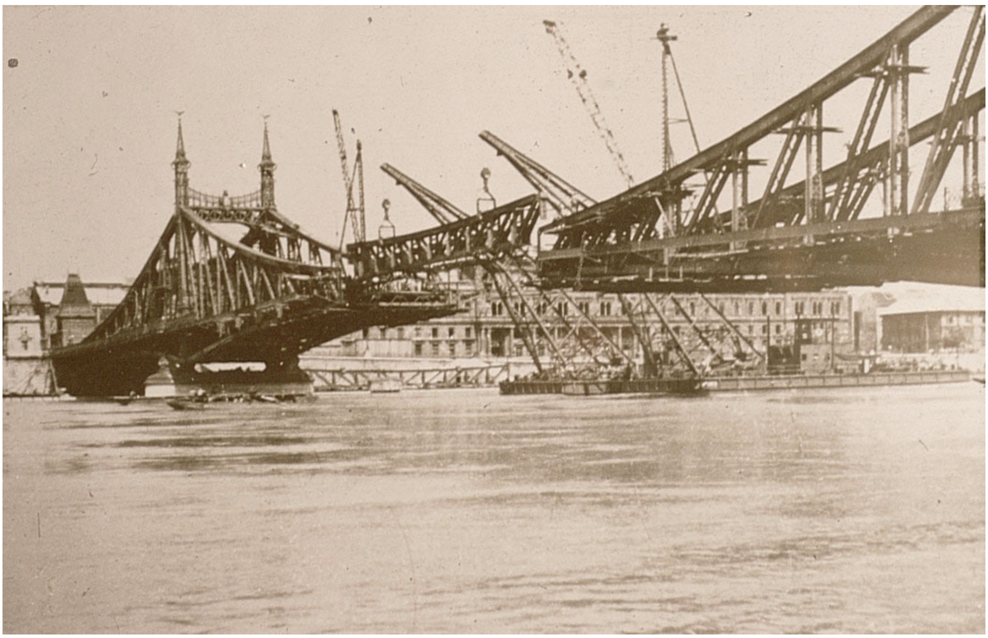

Figure 10: Erection of the midspan of the Bridge (1946)

5. Rehabilitation of Liberty Bridge (1985-1986)

The next step of rehabilitation became necessary in 1985, when the replacement of the side walks and the repair of main elements were performed. [Iványi, M. 1998] There were same corrosion of different parts of the bridge.(Fig. 11).

Figure 11: Original states of the pavements

During this process, because of very heavy corrosion damages of some members of the main girder, a local collapse developed in a column of the main truss. After it the corroded parts of the main trusses were strengthened. (Fig. 12)

The bridging scheme as, planned by Dr. Antal Szittner was the following.

Figure 12: Temporary strengthening of the collapsed member

Figure 13: Reconstructed of the member

Vertical and diagonal members of the main trusses are led through the slab of the side walks, practically without any gap, which is the “result” of a previous repair. Dust and salted sand, were thrown in winter time, caused very heavy corrosion. Cross section reduction of the diagonals was around 10%, while that of verticals exceeded 40% in some cases.

During the rehabilitation process, the one of the mostly damaged columns in its complete cross section broke and moved 15 mm downward and 35 mm sideways. The traffic was closed immediately; provisional fixing elements were built in by HSFG bolts. (Fig. 13)

The reconstruction (1985-1986) started with the determination of the remaining force in the damaged member. Applying the trepanation method, strain gages were bonded to the elements of the column. Drilling pairs of hole near the ends of strain gages, the remaining stresses could be measured and the total force was calculated. The active force in the column was found as 871 kN instead of 1930 kN, calculated from the dead loads.

Special devices and technology were designed to achieve the necessary position of the column ends, to replace the damaged part and to induce the required monitored force into the column. The complete process was continuously controlled and measured.

The renovation of the broken bar was carried out in the following steps (Fig. 14).

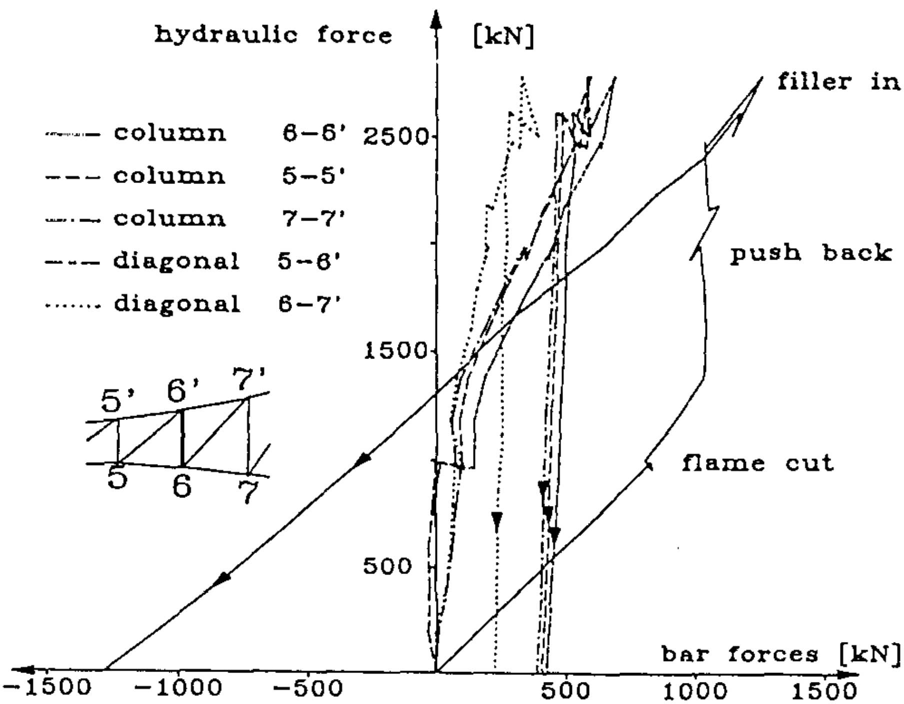

Figure 14: Bar forces vs. hydraulic lifting force during the repair process

(a) At 20 kN hoisting force the provisional fixing elements were removed.

(b) The force was slowly increased until the compression force in the broken bar decreased to zero. This in fact happened at 1000 kN, because the raising force was partially taken by the neighboring parts. At this point, the column was fully flame cut at the plane of the damage. No significant effect of the cutting process was observed at any of the measuring points.

(c) The force was increased further, up to 2000 kN. Here, the horizontally shifted bar end of the upper part was forced back to its proper place by two 50 kN jacks.

(d) Increasing the force up to 2500 kN, the position of the broken bar ends were temporarily fixed. The damaged sections were removed and the two opposite butt ends were cut plane.

At a force of 2800 kN, the gap between the butt ends opened wide enough for a prefabricated element of 200 mm height to be put into it. Now decreasing the hoisting force back to 2500 kN, four new cover plates were welded to the flanges, then connected by precision bolts to 'the angles.' The bar ends were also welded to the fitted in order to ensure the continuity of material and a more favorable transmission of force.

(e) The repair was finished by unloading the hydraulic system, i.e., by transmitting the force from the trimming structure to the repaired column. While unloading, the transfer of the load to bar No. 6-6' was found to be linear. The reduction of the lifting force from 2610 kN to zero resulted in a measured compression force of 2548 kN in the upper part of the bar, and, in 2816 kN, in the lower.

To examine the behavior of the repaired part of the main trusses local loading tests were carried out. The live load intensity in the column reached the maximum design value. The difference between the actual and calculated behavior was realistic.

At the end of the reconstruction work the complete bridge was tested again using 30 trucks of 20 t each.

6. The reconstruction of deck system (1998).

In the middle of the 1990's, it was found that the floor system of the bridge showed corrosion, which necessitated further rehabilitation. Heavy corrosion was also found in the stringers and the cross beams. The two bottom structural parts of the bridge have therefore been scaffold. At the summer 1998 of the preparation of this material, the last phase of the work was being done.

7. Reconstruction of the bridge (2007-2009)

The commencement of works occurred on May 2. 2007. [Kovács, 2010]
In the first phase, painting of structural parts over roadway level was performed simultaneously to the maintenance of tram traffic. This is the period when jointed welding was substituted foe the welded diagonal braces (X-braces) made on main beams during the renovation after the War.

Following a hermetic folio insulation of the metal structure the surface were cleaned by means of installations and procedures for recuperation metal shot penning, then a polyxyloxane layer was applied standing for durable coating.

A special attention had to be paid to the observance of health and environmental protection regulations related to the lead painting removed. The full closure of the bridge occurred on August 21. 2007. Following this, various works on the roadway and on one sidewalk were carried out.

Full scaffolding of the lower bridges parts, demolition of sidewalk and roadway were carried out on that occasion. Construction-demolition of the bridge deck was first carried out on half bridge width, in order to enable servicing of works on the other bridge half. Demolition was carried out by the cutting up of old reinforced concrete pieces by means of diamond-cutter crowns and by direct lifting out of smaller individual pieces. The substitution of the water supply pipes located on the bridge was part of the reconstruction works.

A metal structure was substituted for the former reinforced concrete slab of the bridge sidewalk. Longitudinal beams of the bridge were replaced, too. Due to new sizing regulations, this operations has the consequence of a partly co-action between longitudinal beams and reinforced concrete bridge deck, as well as partly sliding connection between them.

Corrosion protection of metal counterweights and counterweights boxes was also carried out. This operation was solved by the construction and loading of a temporary support above the bridge stability. Corrosion protection of counterweights was not carried out on the bridge, but in a work site located farther. Such works were performed also on the other half bridge in the second phase. The tram track on the bridge was reconstructed as well.

Bridge reception following renovation occurred on May 29. 2009.

8. Summary

The "Ferenc József" (1896-1946), "Szabadság" Liberty Bridge (1946-) was completed in 1896. Originally the bridge was built by wrought iron, after the Second World War it was used different steel materials, therefore the refurbishments of the Liberty Bridge are complicated task.

During the decades the Liberty Bridge is being an ornament and jewel of Budapest, but also a symbol of the Hungarian Capital development to a metropolis.

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