OBSERVATION REGARDING THE BEHAVIOUR OF EXISTING STEEL TRUSS GIRDER BRIDGES WITH LARGE SPANS

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Summary: *At the end of the 19th and the beginning of the 20th century many of steel truss girder bridges – for large spans, were conceived as semi parabolic truss girders. Some of these structures are still in operation on the railway network, or isolated as highway bridges. The live loads increased in time; for the railway bridges in present the UIC 71 convoy and for highway bridges the EC 1 loads are required. The ratio between the dead load (which remained the same) and the live load (which increased), can lead to some interesting observations, regarding the stresses in some bridge elements. This situation can be observed in many existing bridges situated in South – Est of Europe.*

Keywords: *parabolic truss girder, counter diagonals*

1. PARABOLIC TRUSS GIRDER BRIDGES, WITNESSES OF THE PAST - INTRODUCTION

Parabolic or semi-parabolic (half-parabolic) truss girder bridges were used in the majority of cases at the end of the 19th century and the beginning of the 20th [1]. Due to the classical advantages of these structures, they covered a large domain, from spans of 30-100 m.
For larger spans, in these time cantilever truss girder were chosen. The general form of these structure is presented in
Figure 1; the upper (lower) chord is curved, the diagonals are descending ones (tensioned). Compared to a truss with parallel chords, there is an increase in the fabrication cost, but for medium and large spans the additional cost may be balanced by saving in material. The aesthetic appereance of these structure is pleasant, some of the parabolic truss girder bridges, are monuments of the engineering art.

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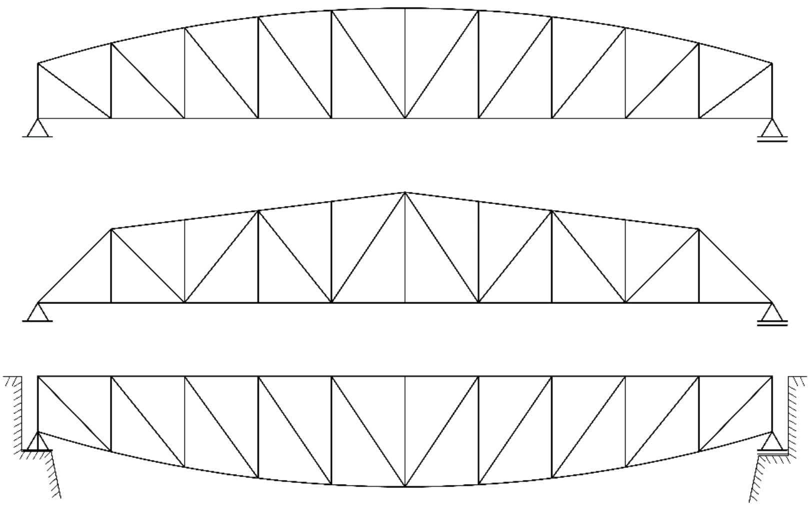

Figure 1. Different forms

A large number of these structures, having an age of 100 or even more years, are still in use on the main railway lines and as isolated structures on the highway network.

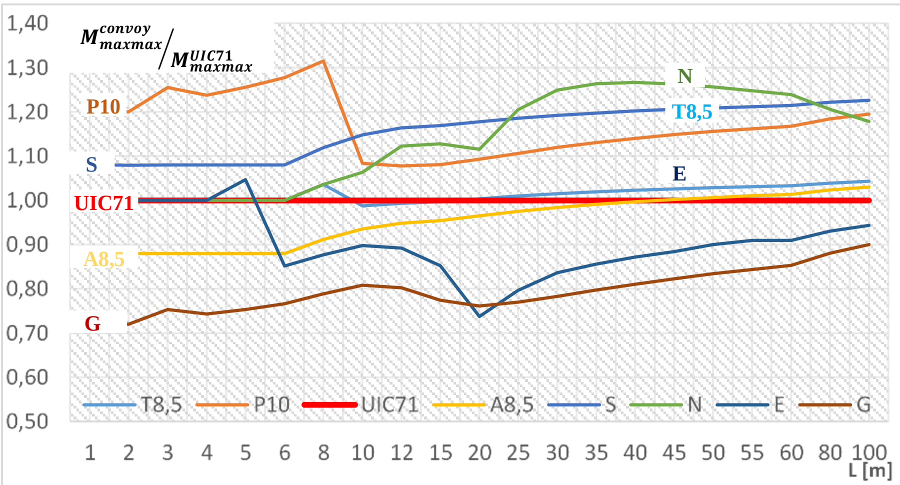

Figure 2. Historical convoys action on railway bridges related to UIC71 load model.

For a rapid evaluation of the carrying capacity of the structure the ratio $M^{convoy}_{maxmax}/M^{UIC71}_{maxmax}$, was calculated and represented in Fig. 2. In this way the present situation of the bridge can be easy appreciated [2].

2. STATICALLY BEHAVIOUR OF PARABOLIC TRUSS GIRDER BRIDGES [3]

In Figure 3 a simple parabolic truss girder is presented.

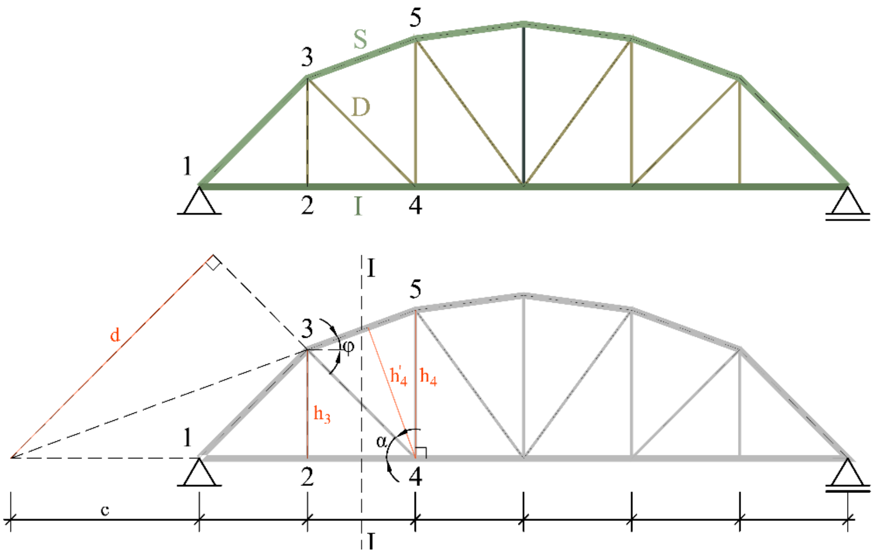

Figure 3. Efforts in a simple parabolic truss girder.

In section I-I, the efforts are:

$$\sum y \qquad -D\times\sin\alpha + S\times\sin\varphi + T_I = 0$$

$$\left(\sum M\right)_4 \qquad S\times h_4\times\cos\varphi + M_4 = 0$$

$$h' = h_4\times\cos\varphi$$

$$S = -\frac{M_4}{h_4 cos\varphi}$$

$$\left(\sum M\right)_3 \qquad I\times h_3 - M_3 = 0$$

$$I = \frac{M_3}{h_3}$$

$$D\times\sin\alpha = -\frac{M_4}{h_4\times\cos\varphi}\times\sin\varphi + T_i$$

The projection equation about the horizontal direction leads to:

$$D\times\cos\alpha + S\times\cos\varphi + I = 0$$

$$D\times\cos\alpha = \frac{M_4}{h_4} - \frac{M_3}{h_3}$$

Usually $M_4 > M_3 > 0$; the sign of the effort in the diagonal bars depends on the variation of bending moment M and the form of the girder. Generally (1):

$$D_i \times \cos\alpha = \frac{M_{i+1}}{h_{i+1}} - \frac{M_i}{h_i}$$

Where M_i and M_{i+1} are the bending moments of similar simple supported girder.

For a girder with parallel chords (*Figure 4*) the efforts in the diagonals are:

$$D \times \cos\alpha = \frac{1}{h_0} \times (M_{i+1} - M_i) \text{ or } D_i = \frac{T_{(i)-(i+1)}}{\sin\propto}$$

With: g – the dead load and p – the live load (convoy), the efforts in the diagonals are:

$$D \times \sin\alpha(\max) = g \times (\Omega_r - \Omega_l) + p \times \Omega_r$$
$$D \times \sin\alpha(\min) = g \times (\Omega_r - \Omega_l) - p \times \Omega_l$$

The aria of the influence line for D_i:

$$\Omega_l = \frac{0{,}5d}{\sin\alpha}, \qquad \Omega_r = \frac{2d}{\sin\alpha}$$

and for D_{i+1}:

$$\Omega_l = \frac{0{,}89d}{\sin\alpha}, \qquad \Omega_r = \frac{1{,}39d}{\sin\alpha}$$

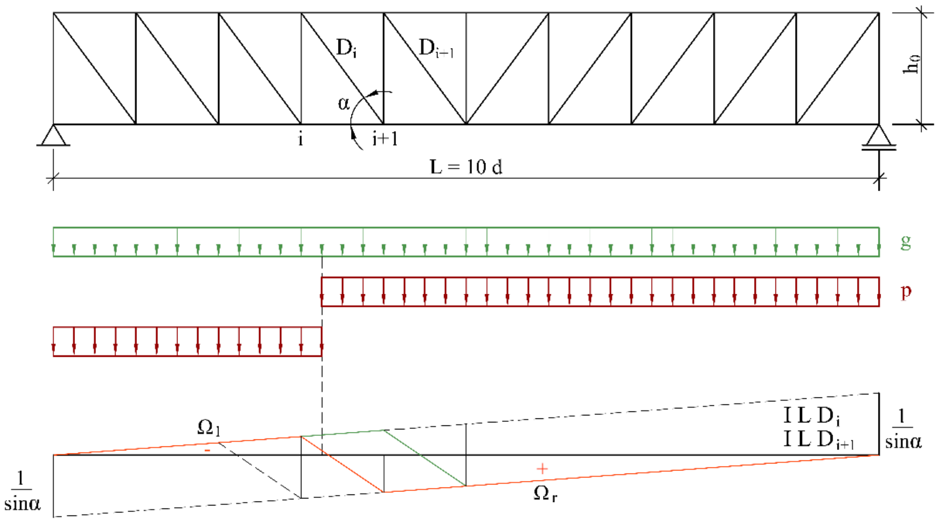

Figure 4. Truss girder with parallel chords.

The load evaluation was performed for two spans: L = 50 m and L = 100 m.
For the dead load g, the expression [1]: $g = 26L + 1700$, was used. The UIC71 convoy was considered for the live loads p, with a dynamic coefficient of 1,2.

L = 50 m

$$g = 26\times 50 + 1700 = 30\ {}^{kN}/_{m}$$
$$p = 1{,}2\times\frac{155\times 6{,}4 + (50-6{,}4)\times 80}{2\times 50} = 54\ {}^{kN}/_{m}$$

L = 100 m

$$g = 26\times 100 + 1700 = 43\ {}^{kN}/_{m}$$
$$p = 1{,}2\times\frac{155\times 6{,}4 + (50-6{,}4)\times 80}{2\times 100} = 50{,}4\ {}^{kN}/_{m}$$

Finally the efforts in the diagonals are:
L = 50 m

$$D^{+}_{i\,max} = 30\times(2-0{,}5)\times\frac{d}{sin\alpha} + 54\times\frac{2d}{sin\alpha} = 153\frac{d}{sin\alpha}$$
$$D^{-}_{i\,max} = 30\times(2-0{,}5)\times\frac{d}{sin\alpha} + 54\times\frac{0{,}5d}{sin\alpha} = 72\frac{d}{sin\alpha}$$

L = 100 m

$$D^{+}_{i\,max} = 43\times(1{,}39-0{,}89)\times\frac{d}{sin\alpha} + 50{,}4\times\frac{1{,}39d}{sin\alpha} = 91{,}55\frac{d}{sin\alpha}$$
$$D^{-}_{i\,max} = 43\times(1{,}39-0{,}89)\times\frac{d}{sin\alpha} + 50{,}4\times\frac{0{,}89d}{sin\alpha} = -23{,}36\frac{d}{sin\alpha}$$

The descending diagonal is compressed.
Obs: The effort in the diagonal depends on the height of the girder only trough $sin\alpha$.
Coming back to relation (1), the bending moments given by the dead load and live loads in i and i+1 are calculated.

$$M_i^g = 12d^2g \qquad M_{i+1}^g = 12{,}5d^2g$$
$$M_i^p = 6{,}96d^2p \qquad M_{i+1}^p = 5{,}88d^2p$$
$$M_i = 18{,}96d^2(g+p) \qquad M_{i+1} = 18{,}38d^2(g+p)$$
$$\frac{M_{i+1}}{M_i} = \frac{h_{i+1}}{h_i} => \frac{18{,}38}{19{,}96} = \frac{h_{i+1}}{h_i} => h_{i+1} = 0{,}97h_i \qquad (2)$$

The result gives the unusual form for the main truss girder presented in *Figure **5***. For the aesthetic reasons in the central panels of the truss girder parallel chords are disposed.

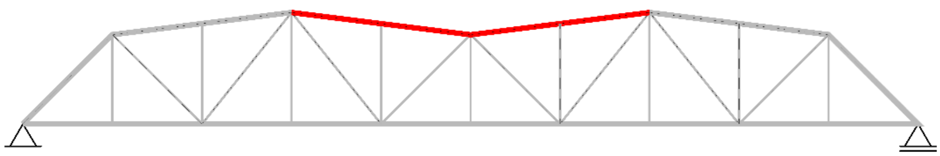

Figure 5. Truss girder resulting from formula (2)

In the German literature this structure are called “Schwedler trusses”. For large spans it is possible that the central descending diagonals are compressed; for this reason counter diagonals are recommended, disturbing the aspect of the structure (

***Figure** 6*)

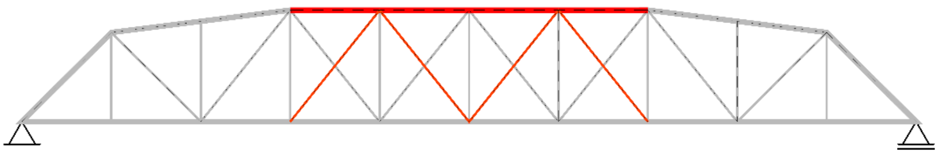

Figure 6. Truss girder with counter diagonals

3. CASE STUDIES

The first analyzed structure is the railway bridge in Mehadia (main line from Timisoara to Bucharest), erected in *Figure **7***.

Figure 7. The Mehadia bridge during a test realized in 1987

The structure is a half parabolic truss girder with a large span of L=101,76 m.

Figure 8. The Mehadia bridge

The central diagonal of the bridge (*Figure 8*) under the self weight and the UIC 71 Convoy is compressed. With a very high slenderness it is obviously that the diagonal does not resist in compression. An analysis performed with rigid joints, leads to a similar result. If the structure resists, it is due to the redistribution of the efforts on the level of deck network girders.
Generally, after 1919, these type of structures were executed with counter diagonals (*Figure 9*)

Figure 9. Railway bridge with counted diagonal

For highway bridges the situation is more favorable. The possibility of compression efforts in the central diagonal can be avoided by providing a stronger diagonal.
In *Figure 10* the bridge in Bocsig is presented; the cross section of the central diagonal is made up by four angles.

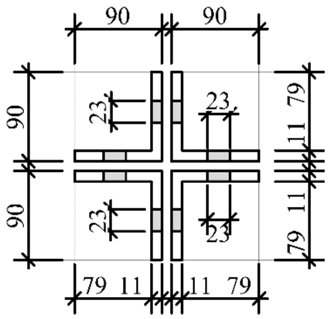

Figure 10. Highway bridge in Bocsig

4. CONCLUSIONS

Half parabolic truss girder bridges as witness of the past are still in use on the main railway lines and on secondary highways. Live loads increased in time; in this situation it is possible that the central descending diagonals are compressed. A special attention must be paid to these elements.

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