INTERNATIONAL SCIENTIFIC CONFERENCE
CIBv 2010
12 – 13 November 2010, Braşov

PROPOSAL FOR THE REHABILITATION OF AN OLD STEEL BRIDGE AT DUMBRĂVENI, COUNTY SIBIU

Zorán VARGA*, Lucian BLAGA*

*Department of Steel Structures, Faculty of Constructions, Technical University Timisoara, Str. Traian Lalescu 2A, 300223, Timisoara, Romania

Corresponding author: Zorán VARGA, E-mail: vargazoran87@gmail.com

Abstract: This paper presents the study of an old steel bridge in Dumbrăveni over the Târnava Mare River, in order to rehabilitate it. The structure was recalculated taking into account the technical condition of the bridge and the actual traffic as well. Finally, a pleading is made for maintaining the over 80 year old historical bridge and several proposals are being formulated for the rehabilitation.

Key words: rehabilitation, maintenance of bridges, steel bridges, strengthening

1. INTRODUCTION

The old steel bridge is located in the city of Dumbrăveni, in the county Sibiu over the Târnava Mare River. It was erected in 1930 at the city entrance on the county road DJ 142C.

Fig. 1 Geographical position of Dumbrăveni

The Romanian Highway Administration Report asserts that the national road network of 16.178 km has 3529 bridges, of which only 83 are steel bridges, the majority in the range of medium spans.
There are a reduced number of steel highway bridges, generally older than 80 years. The technical condition of these bridges is unsatisfactory, even if they are in operation.
The following aspects are to be noticed:
- insufficient clearance, resulting in damages at the vertical members of the main truss girders
- insufficient or no documentation at all
- riveted structures
- poor maintenance, especially corrosion
- the tendency of local authorities to replace the old structures

2. REHABILITATION OF STEEL BRIDGES

The rehabilitation of steel bridges is a complex procedure. The verification methodology adopted by the Romanian Highway Administration is based on the appreciation of the technical condition of the structure made by an expert and transformed into a qualitative expression:

$$\sum_{i=1}^{i=5} C_i + \sum_{i=1}^{i=5} F_i$$

C_i – Quality indexes
F_i – Functional requirements

The quality indexes C and the functional requirements F are given in Table 1.

Table 1. Quality indexes and functional requirements

Quality indexes $C_{1...5}$	**Functional requirements $F_{1...5}$**
C_1 – the main girder	F_1 – traffic condition on the bridge
C_2 – deck elements	F_2 – loading class of the highway
C_3 – infrastructure and bearings	F_3 – year of construction and construction type
C_4 – riverbed	F_4 – quality of fabrication, erection and operation conditions
C_5 – deck surface	F_5 – maintenance of the structure

After every index and requirement is evaluated (marks from 1-10), the total sum expresses the technical condition of the structure, which can be classified as follows:
- very good technical condition;
- good technical condition;
- satisfactory technical condition;
- unsatisfactory technical condition;

- the present technical condition can not assure the safety of the structure.

But this method is suitable only for concrete bridges and for relatively new (30 years) steel bridges, having only an informative character for older steel bridges.

For old steel bridges, a more complex methodology has to be implemented, as shown in Figure 2, using the experience obtained by the verification of steel railway bridges. A simple analysis of the structure is recommended, followed by in-situ tests, which are cheaper for road bridges. Material tests from main or secondary elements are also useful.

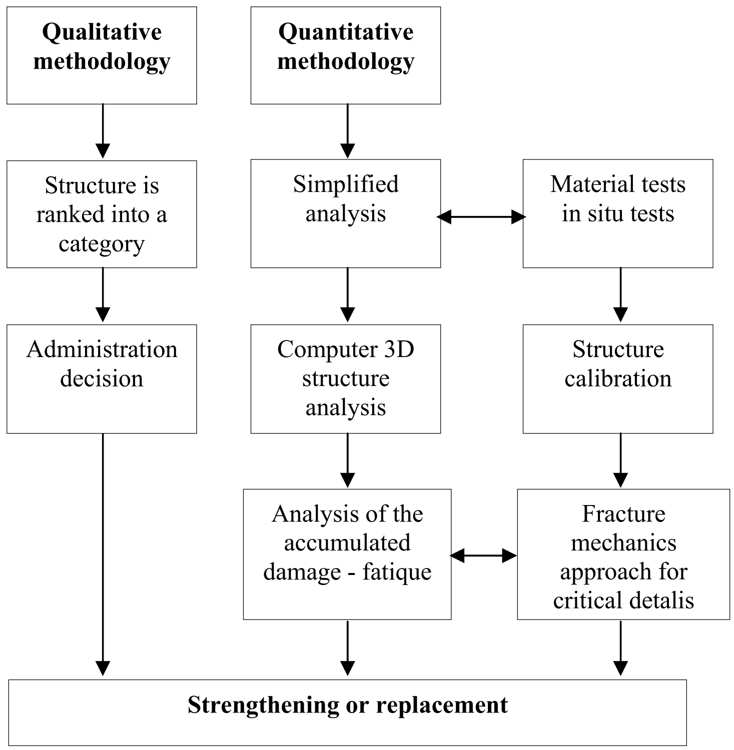

Fig. 2 Proposed improved methodology for the verification of old steel highway bridges

3. DESCRIPTION OF THE BRIDGE IN DUMBRĂVENI

The steel bridge was probably executed around the '30s, over the Târnava Mare River with two equal spans of 43.05 m, resulting a total length of 88 m.

Absolutely no documentation at all is available for the structure, only it's shape and the riveted connections are a hint for the age estimation.

The structure has a classical form: stringers, cross girders and two main parabolic truss girders; the deck is composed by a concrete plate, not older than 20 years.

The general behaviour of the bridge is satisfactory. The lower part of the bridge is affected by corrosion and the maintenance of the bridge is unsatisfactory and un-continuous. The bridge is under the responsibility of the town hall of Dumbrăveni, a city with a population of a little over 12000 inhabitants in the county of Sibiu, in the centre of Romania.

The bridge is the only connection from the main national road DJ 142C to the town.

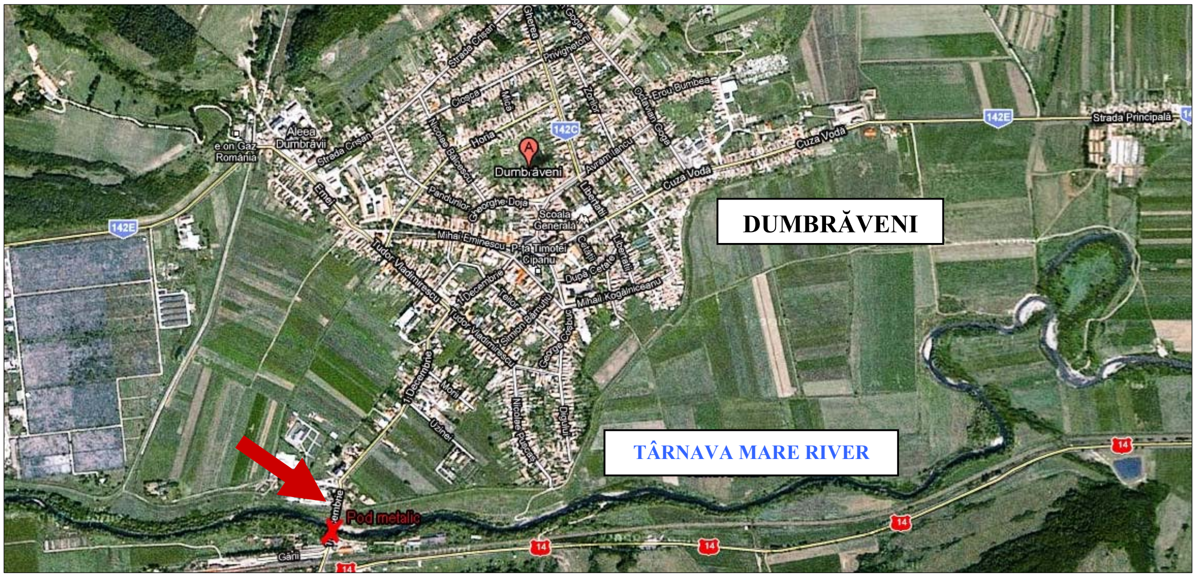

Fig. 3 Position of the bridge in Dumbrăveni

The width of the carriageway is 5.43 m, corresponding to a single lane. There is only one footway, placed on the downstream main girder having a width of 1.4 m. The deck consists of a series of stringers and cross beams, with a concrete plate with the thickness of 20 cm.
The maximum height of the main girder is 6.18 m, corresponding to a ratio L/H = 1/7.
All the connections are riveted.

Fig. 4 General view of the bridge in Dumbrăveni

The main girders of the superstructure consist of truss girders with parabolic chords. The transverse distance between the main girders is 6.41 m.
The lover chord has of two 360x14 webs and two L 100x100x10 angle profiles. The upper chord is made of two 360x14 webs, two L 100x100x10 angle profiles and a 560x10 flange. (Figure 5)

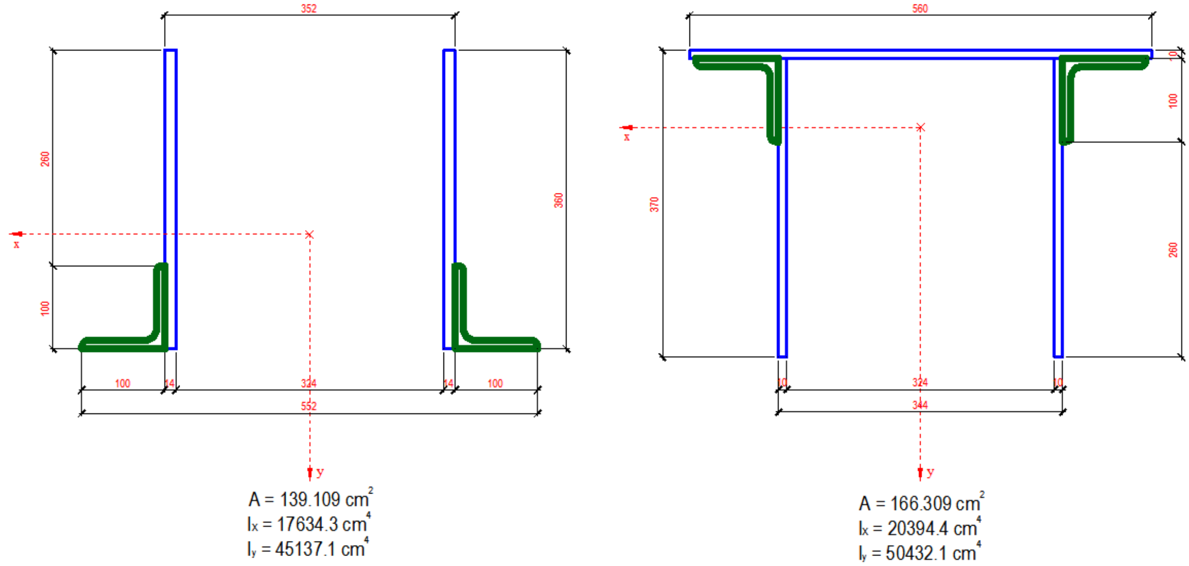

Fig. 5 Cross section – lower chord and upper chord

The struts of the cross girder are formed from a 300x10 web and four angles (LL 120x80x12, LL 20x80x10, LL 100x75x9 or L 80x80x10) and diagonals' cross section consist of four angles (LL 120x80x10 or LL 100x75x9).

Fig. 6 Front view

Fig. 7 Main truss girder

Each deck is supported by four bearings, two fixed and two mobile. Across the bridge there are four fixed and four mobile bearings. The maintenance of the bridge is poor and the elements of the structure are more or less corroded.

Least affected were the elements that allowed the drainage of the water – the struts and the diagonals. The most affected structural elements are the lower chords, the stringers and the cross girders.

Because of the insufficient maintenance over time, bearing devices are also blocked by rust and other impurities (Figure 8 and 9).

Fig. 8 Corroded cross girder

Fig. 9 Bearing device

No road guard exists, for the protection of the main structure against impact of the crossing vehicles.

At this moment, there is an official expertise of the bridge structure with rather negative conclusions - the present recommendation is to replace the structure.

4. VERIFICATION OF THE STRUCTURE

The bridge in Dumbrăveni was the subject of a recent structural analysis. Taking into account the profile and the importance of the road (DJ 142C), the bridge has been recalculated, in order to prove which actual loads and load cases it may sustain.

According to the standards, the following load cases have been taken into consideration:

- Load case 1 – fundamental: dead load, live load
- Load case 2 – supplementary: LC1 + vehicle braking, thermal variations, wind load
- Load case 3 – special: all compatible loads from LC1 and LC2, loads during erection of the bridge, earthquake, agglomeration of pedestrians

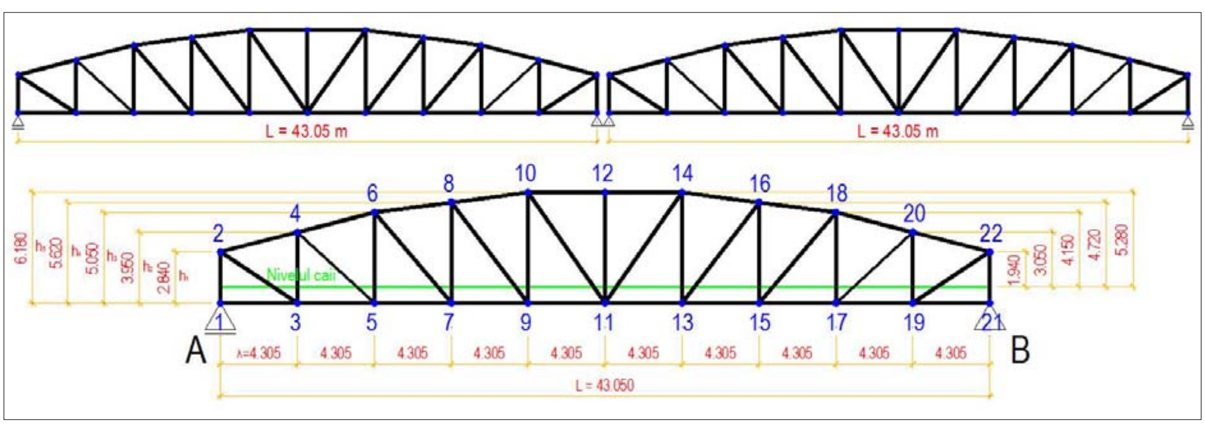

Fig. 10 Static scheme and dimension of the truss girders

The bar tensions have been calculated using analytical influence lines. The dead loads have been estimated on the basis of the measured element geometries and material properties.

The verified convoys, according to the standards and corresponding to the load class E, were the A30 – 30 tonne truck convoy and V80 – special 80 tonne military vehicle (Figure 11). The distance between the A30 vehicles is 10 m and the V80 convoy consists of just one vehicle.

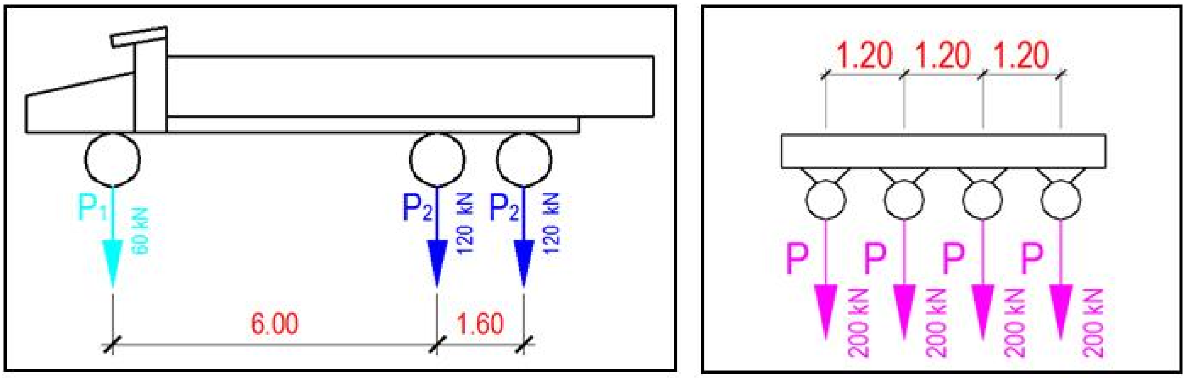

Fig.11 Vehicles of the A30 and V80 convoys

The resulted bar tensions and stresses from the load case 1 are shown in the following tables:

Table 2. Bar tensions and stresses in load case 1, with convoy A30

Lower chord			**Upper chord**			**Diagonal**			**Strut**		
	N[kN]	**σ [N/mm²]**		**N[kN]**	**σ [N/mm²]**		**N[kN]**	**σ [N/mm²]**		**N[kN]**	**σ [N/mm²]**
I_{1-3}	0	0	**S_{2-4}**	-1679.2	126.4	**D_{2-3}**	1446.5	112.8	**V_{1-2}**	-1267.0	128.6
I_{3-5}	1207.4	99.5	**S_{4-6}**	-2112.9	**159.0**	**D_{4-5}**	660.5	91.3	**V_{3-4}**	-568.4	76.7
I_{5-7}	1652.7	102.9	**S_{6-8}**	-2149.8	**160.8**	**D_{6-7}**	511.0	91.3	**V_{5-6}**	-233.0	35.3
I_{7-9}	1931.7	120.2	**S_{8-10}**	-2176.8	**162.8**	**D_{8-9}**	204.2	36.5	**V_{7-8}**	-174.0	28.2
I_{9-11}	1979.5	123.2	**S_{10-12}**	-2073.3	**155.0**	**D_{10-11}**	238.6	42.6	**V_{9-10}**	32.4	3.8
									V_{11-12}	0	0

Table 3. Bar tensions and stresses in load case 1, with convoy V80

Lower chord			**Upper chord**			**Diagonal**			**Strut**		
	N[kN]	**σ [N/mm²]**		**N[kN]**	**σ [N/mm²]**		**N[kN]**	**σ [N/mm²]**		**N[kN]**	**σ [N/mm²]**
I_{1-3}	0	0	**S_{2-4}**	-1719.4	129.4	**D_{2-3}**	1481.1	115.5	**V_{1-2}**	-1262.8	128.2
I_{3-5}	1236.3	101.8	**S_{4-6}**	-2129.4	**165.0**	**D_{4-5}**	728.2	100.7	**V_{3-4}**	-626.7	84.7
I_{5-7}	1714.9	106.7	**S_{6-8}**	-2250.0	**168.3**	**D_{6-7}**	607.3	108.5	**V_{5-6}**	-311.7	47.3
I_{7-9}	2016.1	125.5	**S_{8-10}**	-2311.4	**172.9**	**D_{8-9}**	316.7	56.6	**V_{7-8}**	-272.0	44.1
I_{9-11}	2102.0	130.8	**S_{10-12}**	-2186.3	**163.5**	**D_{10-11}**	388.7	69.4	**V_{9-10}**	382.5	44.4
									V_{11-12}	0	0

The allowable stress according to the standards, for load case 1, is σ_a=150 N/mm^2. The values of the stresses in the upper chord exceed the allowable stress; therefore the bridge is not to be crossed by these convoys.
A further calculation has been made, using just one single A30 vehicle.
The values obtained show that the bridge is suitable for one single 30 tonne truck:

Table 4. Stresses in load case 1, one single A30 vehicle

Lower chord		**Upper chord**		**Diagonal**		**Strut**	
	σ [N/mm^2]		**σ [N/mm^2]**		**σ [N/mm^2]**		**σ [N/mm^2]**
$\mathbf{I_{1-3}}$	0	$\mathbf{S_{2-4}}$	110.19	$\mathbf{D_{2-3}}$	98.37	$\mathbf{V_{1-2}}$	109.36
$\mathbf{I_{3-5}}$	86.71	$\mathbf{S_{4-6}}$	140.24	$\mathbf{D_{4-5}}$	81.43	$\mathbf{V_{3-4}}$	68.43
$\mathbf{I_{5-7}}$	90.73	$\mathbf{S_{6-8}}$	144.64	$\mathbf{D_{6-7}}$	82.50	$\mathbf{V_{5-6}}$	32.5
$\mathbf{I_{7-9}}$	108.17	$\mathbf{S_{8-10}}$	149.26	$\mathbf{D_{8-9}}$	33.81	$\mathbf{V_{7-8}}$	26.17
$\mathbf{I_{9-11}}$	112.97	$\mathbf{S_{10-12}}$	141.70	$\mathbf{D_{10-11}}$	40.08	$\mathbf{V_{9-10}}$	28.22
						$\mathbf{V_{11-12}}$	26.17

Calculations have been undertaken also for the wind bracings, the stringers and the cross beams. While the resulting stresses in the wind bracing are very small and of no concern, the stresses in the stringers and the cross beams resulting from the convoys surpass also the allowable stress.
The allowable stress is only verified using just one single A30 vehicle.
According to the National Road Administration, a 49 tonne truck can occur relatively often in Romania. So the structure was verified for a single A49 vehicle, too (Figure 12).

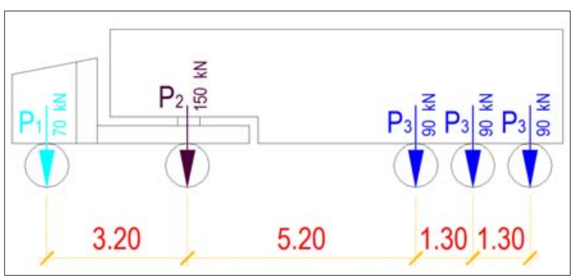

Fig.12 A49 vehicle

Table 5. Stresses in load case 1, one single A49 vehicle

Lower chord		**Upper chord**		**Diagonal**		**Strut**	
	σ [N/mm^2]		**σ [N/mm^2]**		**σ [N/mm^2]**		**σ [N/mm^2]**
$\mathbf{I_{1-3}}$	0	$\mathbf{S_{2-4}}$	121.72	$\mathbf{D_{2-3}}$	110.10	$\mathbf{V_{1-2}}$	122.67
$\mathbf{I_{3-5}}$	95.78	$\mathbf{S_{4-6}}$	**157.94**	$\mathbf{D_{4-5}}$	92.87	$\mathbf{V_{3-4}}$	78.06
$\mathbf{I_{5-7}}$	102.18	$\mathbf{S_{6-8}}$	**161.31**	$\mathbf{D_{6-7}}$	96.08	$\mathbf{V_{5-6}}$	39.62
$\mathbf{I_{7-9}}$	120.64	$\mathbf{S_{8-10}}$	**165.02**	$\mathbf{D_{8-9}}$	43.44	$\mathbf{V_{7-8}}$	33.70
$\mathbf{I_{9-11}}$	124.90	$\mathbf{S_{10-12}}$	**155.08**	$\mathbf{D_{10-11}}$	51.21	$\mathbf{V_{9-10}}$	33.75
						$\mathbf{V_{11-12}}$	0

Such a truck will lead to the exceeding of the allowable stress and therefore is strictly forbidden.

A fatigue verification has also been made, according to the Swiss Standard SIA 161, which offers a high informative diagram in the sense of estimating the circulation in the past.

With an equivalent stress range $\Delta\sigma_e$, resulting from the A30 convoy, smaller than the fatigue resistance $\Delta\sigma_c = 70 N/mm^2$, and therefore the affirmation that, the bridge is old and therefore under the influence of fatigue, is incorrect.

Table 6. Range stresses

Lower chord		**Upper chord**		**Diagonal**		**Strut**	
	$\Delta\sigma_e$ [N/mm^2]		**$\Delta\sigma_e$ [N/mm^2]**		**$\Delta\sigma_e$ [N/mm^2]**		**$\Delta\sigma_e$ [N/mm^2]**
I_{1-3}	0	**S_{2-4}**	29.26	**D_{2-3}**	26.41	**V_{1-2}**	33.49
I_{3-5}	20.95	**S_{4-6}**	35.54	**D_{4-5}**	22.83	**V_{3-4}**	20.62
I_{5-7}	20.93	**S_{6-8}**	35.20	**D_{6-7}**	25.15	**V_{5-6}**	13.41
I_{7-9}	23.96	**S_{8-10}**	34.44	**D_{8-9}**	15.49	**V_{7-8}**	15.18
I_{9-11}	23.72	**S_{10-12}**	33.25	**D_{10-11}**	18.05	**V_{9-10}**	22.60
						V_{11-12}	0

5. CONCLUSIONS

The steel bride at Dumbrăveni over the Târnava Mare was erected in the 1930s and no original documentation does exist, only an expertise from the year 2008, with rather negative conclusions. After undergoing a calculation, on the basis of the Romanian Standards STAS 1844/75 and STAS 1911/98, we can conclude the following:

1. A calculus for the load class E (A30 and V80 convoys) leads to the conclusion that the structure does not resist, the resulting stresses exceeding 10% over the allowance.
2. The stresses in the stringers and in the cross beams do not exceed the allowable stress for the A30 convoy, but the V80 convoy leads to values over the imposed limit.
3. Therefore, the calculations have been repeated, with a single A30 vehicle on one span, leading to the following conclusion:

In the main girder, the stresses produced by the A30 vehicle not exceed the allowable stress (150 N/mm²). Taking into account the age of the bridge, the allowable stress σ_a was considered 150 N/mm2.

Fatigue verification has also been made, according the SIA 161, which take into account the past circulation. It resulted that the structure is not subject of material fatigue, the accumulated damage representing less than 50% of the total damage that could lead to breakage.

This last affirmation leads to the conclusion that the structure can be used and maintained, after being rehabilitated.

The rehabilitation of the structure is not only possible, but also a duty of the local administration, having a historical value and being a witness of the past. The rehabilitated bridge could have an emblematic character as a landmark for the city of Dumbrăveni. Until the beginning of the rehabilitation works, the following immediate measures are imposed:

- Circulation interdiction for the V80 vehicle
- The minimal distance between two trucks will be limited to 40 m. It has to be pointed out, that the transporters have the tendency to overload the vehicles; according to the National

Road Administration, a 49 tonne truck can occur relatively often in Romania. Such a truck will lead to the exceeding of the allowable stress and is therefore strictly forbidden.

- Trucks over 30 tonnes are strictly forbidden.
- Annealing of the road surface on the bridge in order to eliminate the defects that lead to high dynamic coefficients and important damages to the structure

It is to be mentioned, that with minimal reparations (introduction of supplementary angle profiles on the upper chord of the main truss girder) can improve the bearing capacity, assuring the crossing of the A30 convoy.

The rehabilitation of the bridge consists in:

- Unveiling of the concrete plate
- Sandblasting of the structure
- Changing of the high corroded elements
- Realization of on concrete plate with a composite concrete-steel effect

During the rehabilitation works, a provisory bridge shall be erected.
There are 3 solutions for the actual situation of the bridge:
Solution 1:

- Rehabilitation of the old bridge
- Interdiction for trucks over 30 tonnes

Solution 2:

- Rehabilitation of the old bridge, only for light traffic and pedestrians
- Transformation of the provisory bridge (with two lanes) in a bridge for heavy traffic

Solution 3:

- Rehabilitation of the old bridge, which will be transformed in a technical monument, where cultural activities can be organized
- Bypassing of the whole traffic on the new bridge

REFERENCES

1. *AND 522 – 2002. Bridge Verification Methodology. Romanian Highway Administration*, 2002
2. Bancila R., Petzek E. *Rehabilitation of Steel Bridges in Romania*, Proceedings of the 6th Japanese German Bridge Symposium, Munich, 2005
3. Bancila R., Petzek E., Boldus D. *A general concept regarding the rehabilitation of existing steel bridges*. Proceedings of the 7th International Conference on Steel Bridges: Advanced Solutions & Technologies-Guimarães, Portugal ECCS, 2008
4. Bancila R., Petzek E., Boldus D. *Extended life for old highway bridges from the western part of Romania*. Proceeding of the Workshop COST 25 – Sustainability of constructions. Timisoara, 2009
5. Bondariuc V., Băncilă R. *Poduri metalice. Grinzi cu zăbrele*. Institutul Politehnic „Traian Vuia" Timişoara, 1986
6. Bondariuc V., Băncilă R. *Poduri metalice. Calculul si proiectarea.* Institutul Politehnic „Traian Vuia" Timişoara, 1983
7. Bondariuc V., Băncilă R. *Probleme speciale de poduri metalice*. Institutul Politehnic „Traian Vuia" Timişoara, 1989
8. Petzek E. *Siguranţa în exploatare şi reabilitarea podurilor metalice*. Doctoral thesis. Universitatea „POLITEHNICA" Timişoara, 2004.
9. *SIA 161.Stahlbauten*, Schweizerischer Inginieur- und Architekten-Verein, 1990
10. *STAS 1844-75. Steel highway bridges. Design of the superstructure*

Received September 20, 2010