

SUSTAINABLE DECONSTRUCTION OF TWO BRIDGES

D. BOLDUS¹ A. SCHWALIE¹ A. FEIER¹
R. BANCILA¹

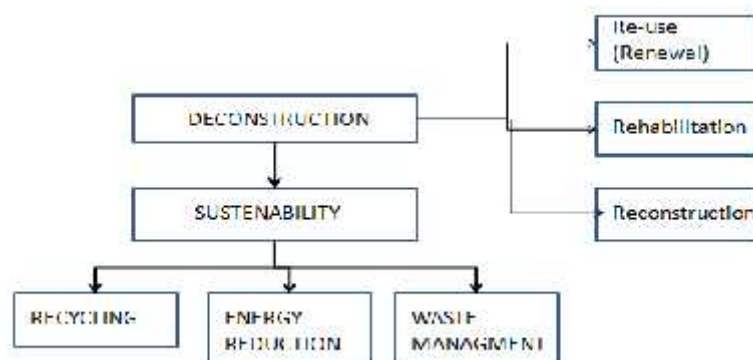
Abstract: *Deconstruction is an actual concept strongly correlated with sustainability. When existing structures are not more able to fulfill the present needs, deconstruction can give them a second life with regard to the sustainable concept of development. Deconstruction includes renewal, rehabilitation or reconstruction; it is more economically to refurbish, rather than rebuild. The paper presents two typical examples in this direction: The reconstruction of an existing bridge situated in an active agricultural area and the re – use of a former portal crane girder for a pedestrian bridge.*

Key words: *deconstruction, steel bridges, corrosion, pedestrian bridge.*

1. Introduction–deconstruction Concept

Structures have a life cycle; when structures reach the end of their design life, there are some possibilities to maintain the structures in use: renewal, rehabilitation or

reconstruction. These operations must be correlated to environmental sustainability [1]. Deconstruction helps to save the need for new materials and resources (Fig. 1).



¹ University Politehnica Timisoara, Civil Engineering Faculty.

Fig. 1. *The general concept of deconstruction*

It must be mentioned that deconstruction and demolition have different significances; demolition means that in short time, the site is cleared by brutal methods. Deconstruction includes strengthening of the structure, which is the most environmentally and economically efficient option, practically giving to the bridge a new life. Deconstruction has a special importance in relation with the existing architectural heritage [2].

The deconstruction concept must be considered by the designer together with the contractor in order to assure safety and efficiency; the chosen technical solution must also comply with others criteria such as structural robustness, economics and

easy execution [3]. During deconstruction safety risks can appear. It is necessary that one expert is present on the site in all the important construction phases.

The paper presents two typical examples in this direction.

2. Reconstruction of an Existing Highway Bridge

The bridge “Timi ina” situated on a local highway, connecting two localities in the Timis County, is an existing structure with a neglected maintenance in time. In present the technical condition of the bridge is rather bad (Fig. 2).



Fig. 2. *The existing structure*

The bridge has three spans, each of 7.00 m. The structure is composed by simple supported steel profiles (IPN 320 and IPN 400) and a deck of prefabricated concrete slabs without dowels disposed in 1994 (the former solution had wooden sleepers). The structure has no footpath or handrails. In the last years heavy agricultural machines were introduced in the

agricultural activities; in consequence the bridge is not more able to sustain the activity in this area. The proposal to build a new bridge was discussed; in order to save resources, the renewal including strengthening of the structure was taken. Some ingenious and efficient solutions were adopted (Fig. 3).

- the new red line of the bridge will connect with the red line of the existing road.

For the superstructure, in principle the existing rolled profiles will be maintained and completed with new ones; the beams will be strengthened by ties; elastomeric bearings and seismic devices will be introduced, wind bracings are disposed. The existing profiles IPN 400 will be reused, after sand blasting and painting (disposed as marginal beams, 1 and 5) and adding new profiles IPN 320 which will be

transformed into 2 IPN - (twin) beams, longitudinally welded, constituting intermediate beams 2 and 4 in marginal and central span and finally the introduction of a new central beams (gr. 3) of IPN 400. All steel beams are reinforced with 2 round steel tie-rods with a diameter $D = 28-35\text{mm}$ of high-quality steel with high tensile strength - $f_{yk} = 600-900\text{ N/mm}^2$ (Fig. 6). The final constructive depth is equal to $h_c = 0.83\text{m}$. Neoprene bearings are disposed on the piers and abutment.

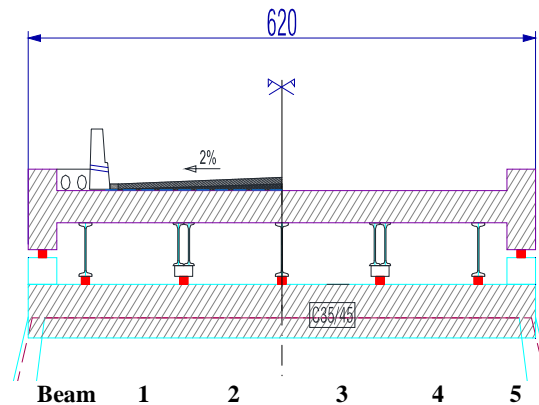


Fig. 5. New bridge - deck

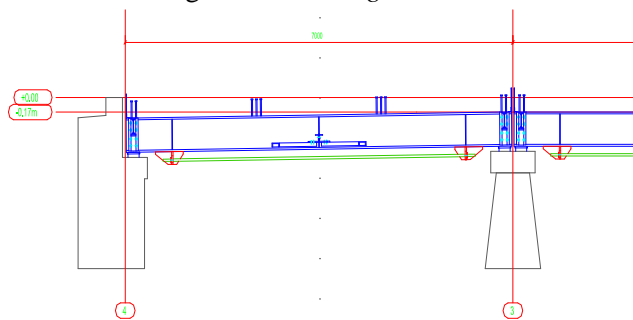


Fig. 6. Strengthening with steel ties

The deck will be realized independent in each span; the existing precast slabs $550 \times 200 \times 17\text{ cm}$, are maintained (after pressure water cleaning) and reinforced by in situ concrete topping; intermediate concrete cross girders are introduced,

which are connected to the steel girders with NELSON $19 \times 200\text{ mm}$ shear connectors, realizing the composite action. The final thickness of the deck is 24 cm (Fig. 7).

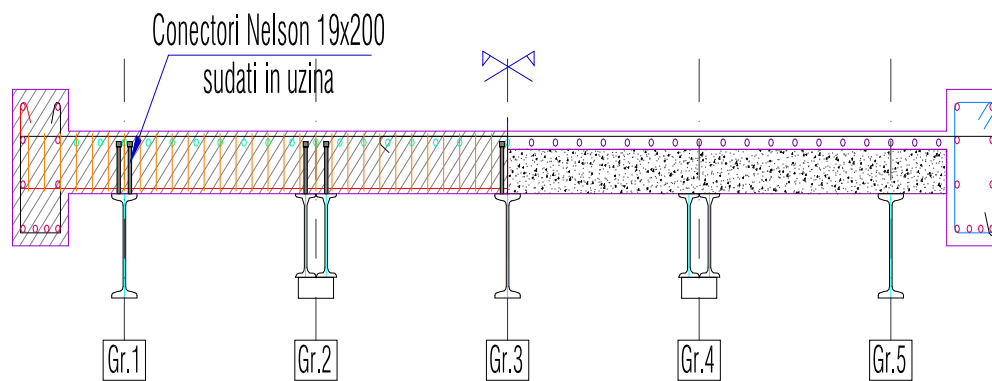


Fig. 7. Bridge deck with cross girders

The proper water drainage and waterproofing will be assured; the deck will be made of asphalt concrete; the sidewalks of concrete will be protected by

a two-component epoxy-colored (yellow, white, cream) resin and quartz sand.

The structure was calculated to the Eurocode LM 1 convoy.

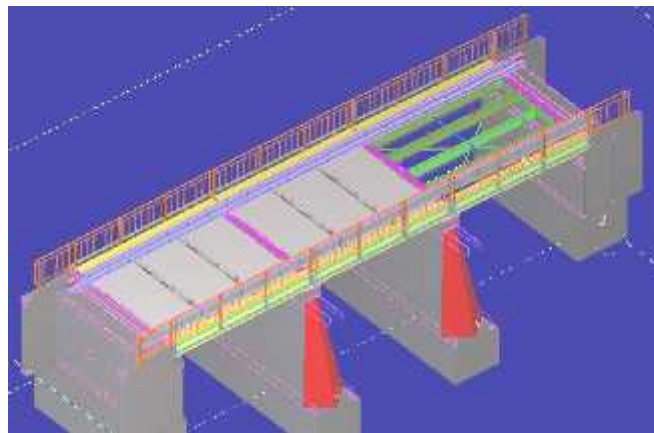


Fig. 8. General view of the renewed structure

The structure is now able to take the present heavy standardized loads (Fig. 8).

3. Re-use of an Crane –Girder for a Footpath Bridge

The second example refers to a former disaffected portal crane girder. An existing portal crane constructed in 1979 was disaffected, in an enterprise in the town of

Bistrița (Fig. 9). The characteristics of the crane are: $Q_{max} = 20/5$ Tones and $D=20+2 \times 6$ m. The main girders have a box girder cross section, with $b=650$ mm and $h=1300$ mm in the field, respectively 700 mm on the bearings. The web is 8 mm thick supporting the crane rail. Statically it is a cantilever girder with $L=6.00 + 20.0 + 6.00$ m. Both main girders situated at a distance of $B=4208$ mm, are connected at

the end with two cross girders. The technical condition of the structure is rather good (Fig. 10); a relative recent general control made by “ISCIR - National Authority for Control and Approval of Boilers Pressure Vessels and Hoisting

Equipment” is positive. Even the thickness of the elements corresponds to the initial values from the project. The welds were verified by the magnetic particle inspection; the result was satisfactory.



Fig. 9. The disaffected crane

The assessment of the structure was performed in accordance with the European Standards [4] and the standards available on the time of the crane construction:

$$S_{Sd} \leq R_{Rd}, \quad \text{Ultimate Limit state - ULS} \quad (1)$$

$$\text{respectively } S_n \leq \tau_a, \quad \text{Method of allowable stresses - MRA} \quad (1.a)$$

and

$$f_{\max} \leq f_a = L/350 \quad \text{Serviceability Limit Stresses -SLS.} \quad (2)$$

A steel equivalent to the present grade S 235 J2G3 (old designation OL 37-4.kf) was accepted, with $f_y=235 \text{ N/mm}^2$. Based on the experience of the experts team, who analyzed a large number of existing steel bridges [5], [6], a partial material safety factor of $\gamma_{M0} = 1.1$ was accepted, resulting the design value of $f_{yd}=213.6 \text{ N/mm}^2$. In parallel, the allowable stress can be assumed by 150 N/mm^2 . The evaluated loads on the bridge were:

Permanent actions G Gk ($\gamma_G = 1,35$)

- Dead load of the main girder
0.85kN/m

- Deck (slabs with 13 cm thickness)
3.25 kN/m²



Fig. 10. General view of the crane girders

Variable actions $Q_{k,1}$ Q_k [7] $Q_{k,1} = 1,5$
and $\psi_{0,i} = 0,7$:

- LM-4 load model for people crowd on the bridge.....= 5 kN/m²
- Snow load $s_{0,k} = 2.0 \text{ kN/m}^2$
- $S_k = 1.2 \times 0.8 \times 2.0 = 2.0 \text{ kN/m}^2$

The considered load combinations are:

- Carrying capacity – ULS

C1:

$$\sum X_G G_k + X_{Q,1} Q_{k,1} + \sum_{i \geq 2} X_{Q,i} Q_{k,i} \quad (3)$$

- Deformation - SLS

C2:

$$\sum G_k + Q_{k,1} + \sum_{i \geq 2} Q_{k,i} \quad (4)$$

The statically scheme of the structure is a simple supported girder with a span of 37,40 m (Fig.11).

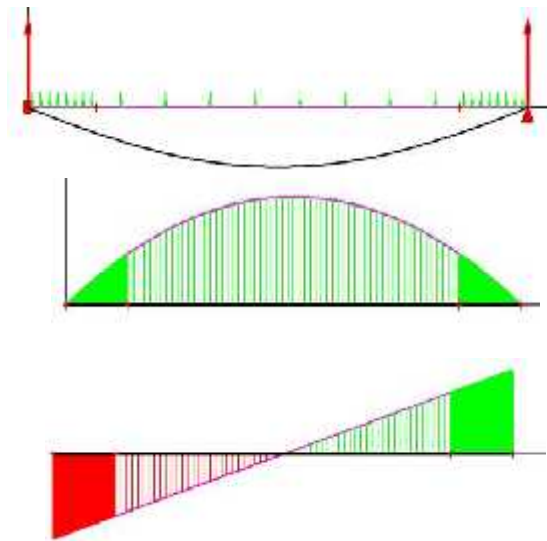


Fig. 11. Statically scheme of the crane girder

The calculated values for the ULS limit state (Design value for the bending and shear resistance), are:

- marginal cross section $l = 5100\text{mm}$:

$$M_{1,el,Rd} = W_y x f_{yd} = 6363 \times 10^3 \times 213.6 \times 10^{-6} = \mathbf{1359 \text{ kNm}}$$

$$V_{1,pl,Rd} = A_w x f_{yd} / 3^{1/2} = 9800 \times 213.6 / 3^{1/2} \times 10^{-3} = 1208.6 \text{ kN}$$

$$V_{1,Rd} = 0.5 \times V_{pl,Rd} = 0.5 \times 1208.6 = \mathbf{604.3 \text{ kN}}$$

- middle of the span

$$M_{2,el,Rd} = W_y x f_{yd} = 13634 \times 10^3 \times 213.6 \times 10^{-6} = \mathbf{2912 \text{ kNm}}$$

$$V_{2,pl,Rd} = A_w x f_{yd} / 3^{1/2} = 18200 \times 213.6 / 3^{1/2} \times 10^{-3} = 2245 \text{ kN}$$

$$V_{2,Rd} = 0.5 \times V_{pl,Rd} = 0.5 \times 2245 = \mathbf{1122.5 \text{ kN}}$$

The calculated design values for the bending and shear force are presented in Table 1.

The calculated design values for the bending and shear force Table 1

Simple supported girder	Loads	Cross section	ULS	
			MSd	VSd
		X = ...m	[kNm]	[kN]
Design value for the bending moment MSd	Gd + LM-4	5.10	+3614	818
Design value for the shear force VSd		Middle	+7672	597
Design value for the bending and shear resistance	SRd		1359/2912	604/1122

The condition $S_d \geq R_d$ is not fulfilled. In order to strengthen the structure, new material are added (direct strengthening), increasing the cross section of the structure (variable cross section).

In order to evaluate the remaining fatigue life of the structure a stress history was recovered and the accumulated damage according to the Miner rule was evaluated:

$$D = \sum \frac{n_i}{N_i} \leq 1 \quad (5)$$

According to the existing documentation the working program of the crane was 48 cycles/day with 25 % of the maximum capacity ($k_p=0.25$), 240 days/year in a period of 34 years of functioning. With the EC 3 rules (constructive detail $c = 80$ N/mm² SR EN 1993-1-9, tab.8.2, 8.3 and 8.4), a damage of $D=0.018 \ll 1.0$ was obtained, which is insignificant.

The final proposal is presented in Fig.12. A pleasant architectonic effect is obtained by placing at different levels the pedestrian and the cycling (bike) lane.

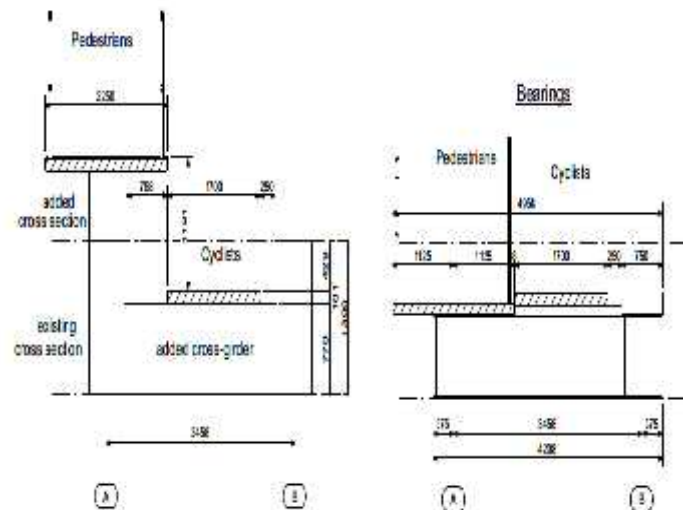


Fig. 12. Final proposed solution

The footbridge will be placed in the center of the Bistrița town realizing the access of the pedestrians and cyclists to a picturesque recreation area (Fig. 13).



Fig. 13. Location of the future pedestrian bridge

3. Conclusions

The deconstruction must be conceived in accordance with all the interested factors, in order to assure safety and efficiency; the chosen technical solution must also comply with others criteria such as structural robustness, economics and easy execution [8].

Deconstruction is based on the ability of the expert and designer. Generally, deconstruction is not recommended if the additional material is more than 40 % from the weight of the existing structure or 30 % of a new one, or when the rehabilitation cost is higher than the price of a new structure [9]. Exceptions are the historical structures [10].

In conclusion by applying the deconstruction concept even in apparently less important situations, the existing structures can be reused, saving money and environmental resources.

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