Re-use of an existing steel structure as part of sustainable development

A. Feier [1,2,3], A. Radomir [3], R. Băncilă [3]

[1]University “Politehnica”, Timişoara, România, [2] INCD URBAN INCERC, Timişoara, Romania,
[3] Romanian Welding Association

E-mail: anamaria_butisca@yahoo.com.au

Keywords

Re-use, steel structures, corrosion, pedestrian bridge.

1. Introduction: Re-using 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]. This concept helps to save the need for new materials and resources (Fig. 1).

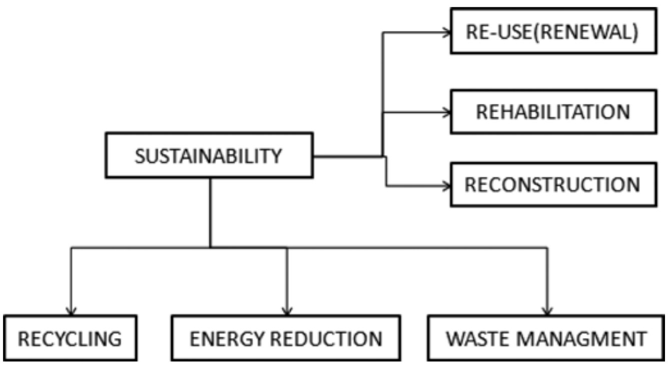

Figure 1. The general concept of sustainability for existing structures.

The re-using 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 [2]. During re-using safety risks can appear. It is necessary that one expert is present on the site in all the important construction phases.

Reusing the existing steel structures is an integral part of the sustainable development. In the developed societies, as they progress, the feeling grows that it is necessary to maintain the existing structures, especially the historical ones [3].

2. Re-use of an crane – girder for a footpath bridge

Existing old steel structures are in the majority of cases dismantled. Taking in account the technical condition of the structure, a re-use, rehabilitation or reconstruction solution can be analyzed.

An example in this direction 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. 2). The characteristics of the crane are: Q_{max} = 20/5 Tones and D=20+2x6 m. The main girders have a box girder cross section, with b=650mm 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=4208mm, are connected at the end with two cross girders. The technical condition of the structure is rather good (Fig. 3); 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.

Figure 2. The disaffected crane.

Figure 3. General view of the crane girders.

The steel girders were proposed for a pedestrian bridge, in the middle of the town of Bistrița connecting the two parts of

Sudarea şi Încercarea Materialelor

a natural park very appreciated by the inhabitants (Fig. 6). The first step was the assessment of the structure; it was performed in accordance with the European Standards [4] and the standards available on the time of the crane construction:

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

respectively

$S_{max} \le \sigma_a$, Method of allowable stresses - MRA (1.a)

and

$f_{max} \le fa = L/350$, Serviceability Limit Stresses –SLS. (2)

Variable actions $\gamma_{Q,1}\, Q_k$ [5] $\rightarrow \gamma_{Q,1} = 1{,}5$ and $\psi_{0,i} = 0.7$:

- LM-4 load model for people crowd on the bridge.....= 5 kN/m²
- Snow load S_k= 2.0 kN/m² $\rightarrow S_k$=1.2x0.8x2.0 = 2 kN/m²

The considered load combinations are:
Carrying capacity – ULS C_1:

$$\sum \gamma_G G_k + \gamma_{Q,1} Q_{k,1} + \psi_{0,i} \sum_{i \ge 2} \gamma_{Q,i} Q_{k,i} \qquad (3)$$

Deformation - SLS C_2:

$$\sum G_k + Q_{k,1} + \psi_{0,i} \sum_{i \ge 2} Q_{k,i} \qquad (4)$$

The statically scheme of the structure is a simple supported girder with a span of 37.40 m (Fig. 4).

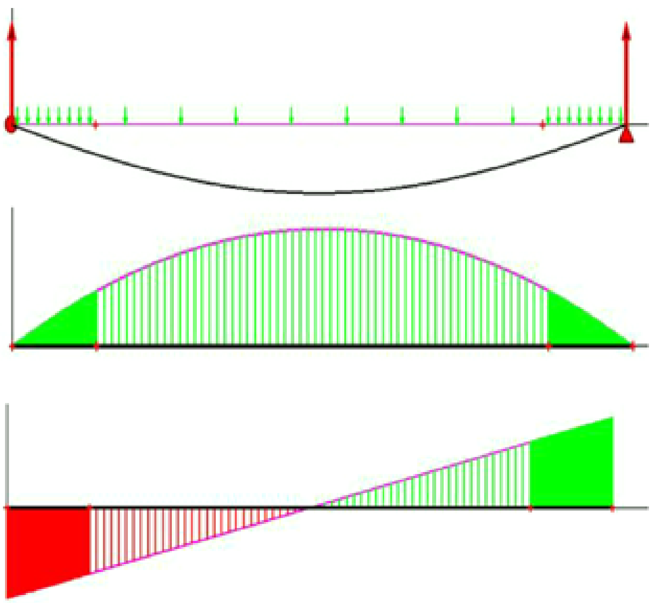

Figure 4. Statically scheme of the crane girder and stress diagrams.

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

- marginal cross section l = 5100 mm:

$M_{1,el,Rd} = W_y$ x f_{yd}= 6363x103 x 213.6 x 10-6 = 1359 kNm;

$V_{1,pl,Rd} = A_w$ x $f_{yd}/3^{1/2}$ = 9800 x 213.6/$3^{1/2}$ x10-3 = 1208.6 kN

$V_{1,Rd}$ = 0.5 x $V_{pl,Rd}$ = 0.5x1208.6 = 604.3 kN

- middle of the span

$M_{2,el,Rd} = W_{yxfyd}$ = 13634 x 103 x 213.6 x 10-6 = 2912 kNm;

$V_{2,pl,Rd} = A_w$ x $f_{yd}/3^{1/2}$ =18200 x 213.6/$3^{1/2}$ x10-3= 2245 kN

$V_{2,Rd}$ = 0.5 x $V_{pl,Rd}$ = 0.5x2245 = 1122.5 kN.

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

The condition $S_d \le R_d$ 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) - Fig. 5.

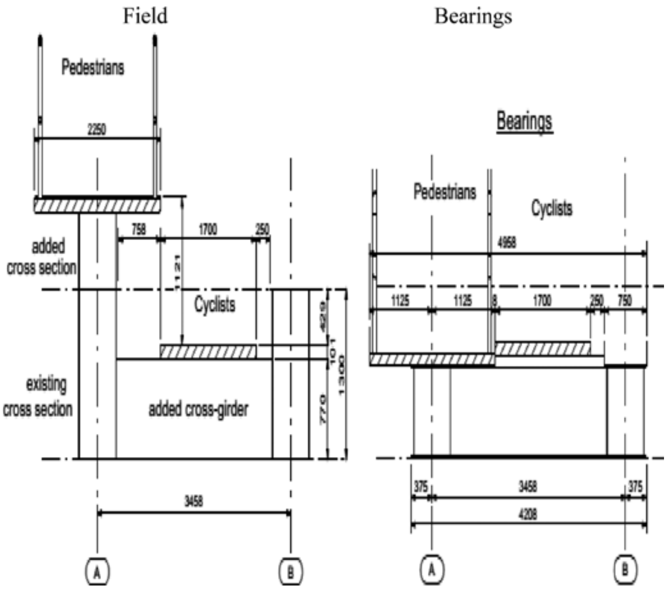

Figure 5. Final proposed solution.

A second important problem was fatigue, 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 [6],[7]:

$$D = \sum \frac{n_i}{N_i} \le 1 \qquad (5)$$

According to the existing documentation the working program of the crane was 48 cycles/day with 25 % of the

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

Nr crt	Statical diagram	Comb	Combinatin description	Section X =...m	ULS M_{Sd} [kNm]	ULS V_{Sd} [kN]	ULS N_{Sd} [kN]	SLS f_1 [Hz]	SLS f_2 [Hz]
1	Gsr	1	G_d + LM-4	5.10	+3614	818	0	3.06	12.07
				middle	+7672	597	0		
2	Gsr+cf	1	G_d + LM-4	5.10	-1944	493	36.5	9.41	21.6
				middle	+2194	347	-516.2		
				brace	~0	~0	-1443		
Compression			S_{Rd}		1359/2912	604/1122	2648/3545		

maximum capacity (k_p = 0.25), 240 days/year in a period of 34 years of functioning. With the EC 3 rules (constructive detail $\Delta\sigma_c$ = 80 N/mm^2 SR EN 1993-1-9, tab.8.2, 8.3 and 8.4), a damage of D = 0.018 << 1.0 was obtained, which is insignificant.

The final proposal is presented in Fig. 5. A pleasant architectonic effect is obtained by placing at different levels the pedestrian and the cycling (bike) lane.

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 (Figure 6).

Figure 6. Location of the future pedestrian bridge.

3. Conclusions

The re-use of existing (old) structures 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].

Re-use is based on the ability of the expert and designer. Generally, re-used is not recommended if the additional material is more than 40% from the weight of the existing structure or 30% of a new one, ore 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 re-using concept even in apparently less important situations, the existing structures can receive a new life, saving money and environmental resources.

Acknowledgement

This paper is supported by the Program NUCLEU: Integrated Researches for Resilience, Efficiency, Safety and Comfort of the Environment Built- "CRESC", Code: PN 16-10.04.05: "Theoretical and Experimental Research on the Impact of Environmental Factors on the Mechanical Characteristics of Wood Elements and Steel Reinforcing elements efficiently embedded in operated safely structures." funded by the Romanian Government- the Romanian National Authority for Scientific Research and Innovation – ANCSI.

References

[1]. „National Sustainable Development Strategy – Romania 2013 – 2020 – 2030" Government of Romania, Ministry of Environment and Sustainable Development, United Nations development Program, National Centre for Sustainable Development, Bucharest 2008.

[2]. Guide for the Structural Rehabilitation of Heritage Buildings, CIB Publication 335 ISBN: 978-90- 6363-066-9, June, 2010.

[3]. E. Petzek, R. Bancila, V. Schmitt "Deconstruction of bridges – Examples", Buletinul Universitatii Politehnica din Timisoara, Tom 54(68) p. 51 - 62, 2009.

[4]. SR EN 1993-1-1:2006: Proiectarea structurilor de oțel

[5]. SR EN 1991-1-1:2004: Acțiuni asupra structurilor

[6]. A. Butisca „Reabilitarea podurilor metalice istorice cu console si articulatii (Gerber),Editura Politehnica, ISSN 1842-581x, 2013

[7]. D. Boldus "Contributii la determinarea capacitatii portante a podurilor metalice vechi in vederea mentinerii lor in exploatare" teza de doctorat Universitatea Politehnica Timisoara, 2002.

[8]. E. Petzek, R. B Băncilă (Editors) "The eight international conference Bridges in the Danube Basin", Proceedings, Springer Verlag, 2013, ISBN 978-3-658-03715-4.

[9]. European Convention for Constructional Steelwork - ECCS "European Steel Design Education Program" ESDEP – Society 2002, Publisher: Brussel Staalinfocentrum

[10]. European Convention for Cons-tructional Steelwork "New life for an existing bridge in Savarsin" European Award 2010, First prize (R. Bancila, E. Petzek, D. Boldus, V. Bondariuc)