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REHABILITATION OF EXISTING STEEL STRUCTURES, AN INTEGRAL PART OF THE SUSTAINABLE DEVELOPMENT

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Abstract: *Sustainable development is a fundamental objective of the European Union and it aims to meet the needs of the present without compromising the ability of future generations to fulfill their own needs. Its goal is the continuous improvement of quality of life and well-being of present and future generations, through an integrated approach between economic development and environmental protection. Rehabilitation of steel structures and historic steel bridges with long life service, is an integral part of maintaining and preserving existing heritage and can be also considered an act of culture. The paper describes the main steps needed to undertake the rehabilitation of existing steel structures and possibility and necessity of a Life-Cycle Costing (LCC) analysis in order to estimate the total cost and the Importance of the rehabilitation works*

Key words: *Sustainable development, Rehabilitation of steel structures*

1. Introduction

The concept of ***Sustainability and Sustainable Development*** appeared in the last 2 – 3 decades. According to the Brundtland Report: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

In the 1970s, the concept of "sustainability" was employed to describe an economy "in equilibrium with basic ecological support systems". The United Nations Millennium Declaration identified principles and treaties on sustainable development, including economic development, social development and environmental protection.

Sustainable development and sustainability derive from the older forestry term "sustained yield", which, in turn, is a translation of the German term "*nachhaltiger Ertrag*" dating from 1713. Sustainability science is the study of the concepts of sustainable development and environmental science. There is an additional focus on the present generations' responsibility to regenerate, maintain and improve planetary resources for use by future generations.

The preparation of the revised National Sustainable Development Strategy (NSDS) [1], is an obligation that Romania has undertaken as an EU Member State in

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conformity with agreed Community objectives and the methodological guidelines of the European Commission.

Sustainable development has developed as a concept through several decades of active international scientific debate and has acquired distinct political connotations in the context of globalization. In the Romanian language , the concept is described by two equivalent terms — *„dezvoltare durabilă”* and **„***dezvoltare sustenabilă*”, that have emerged as synonymous borrowings from different linguistic sources. Existing structures are subjected to processes of degradation with time, which leads to a situation in which in which they became not able to fulfill the purpose for which they have been built.

Sometimes, there is also the need to improve the conditions offered by the existing buildings or to adapt them to new functions.

The rehabilitation of existing steel structures and steel bridges 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 architectural heritage. Rehabilitation of heritage buildings is a way of sustainable development and also an act of culture [2].

Other aspects are:

- Positive socio – economic impact for the region which would be able to obtain the maximum benefit from the rehabilitation of the structures.
- safety a top priority; the rehabilitation program will be conceived to achieve safety and at all construction stages and to allow no compromises during the different construction stages.
- exemplary work sites from an environmental perspective have to be conceived.

The present paper presents the principal steps in the rehabilitation of existing steel structures, with some examples in this direction.

2. Main steps in the rehabilitation of existing steel structures

The estimation of the carrying capacity of existing structures is a complex matter. One of the most important aspects is the experience of the expert. In a first step the expert have to inspect carefully the structure and to make some simple estimations based on simplified analysis methods and a statement about the technical condition of the structure. In figure 1 are presented the main steps in the evaluation of the existing structures.

The expert must see and inspect obligatory the structure; he can ask for some NDT (Non Destructive Tests) tests or even destructive ones in order to establish the material characteristics.

In present in the technical literature, there are – in generally – sufficient data regarding the material qualities, in function of the data when the structure was put in function. In these direction the railway Administrations from Germany, Switzerland, Austria and Hungary, have performed 667 tests [3] on the material collected from existing structures.

For wrought iron (puddle steel) and steel produced before 1900, the following values can be accepted:

- Ultimate tensile strength f_u = 320 … 380 N/mm²
- Yielding stress f_y = 220 N/mm² (survival probability of 95%)
- Young modulus E = 200 000 N/mm²

For the partial safety factor the following values are prescribed: 1,2 for wrought iron γ_R = 1,2 and γ_R = 1,1 for the old steels produced before 1900.

For steel grades after 1925 the following values are recommended:

- Ultimate tensile strength f_u = 370 … 460 N/mm²

- Yielding stress f_y = 240 N/mm² (survival probability of 95%)
- Young modulus E = 200 000 N/mm².

It is interesting to mention that, the Romanian Standard for the Design of Railway Steel Bridges [4], recommends for existing structures produced after 1900,still in a satisfactory technical condition, the following values for the allowable stress:

- σ_a^I =1,5 kN/mm² → mild steel
- σ_a^I =1,4 kN/mm² → wrought iron.

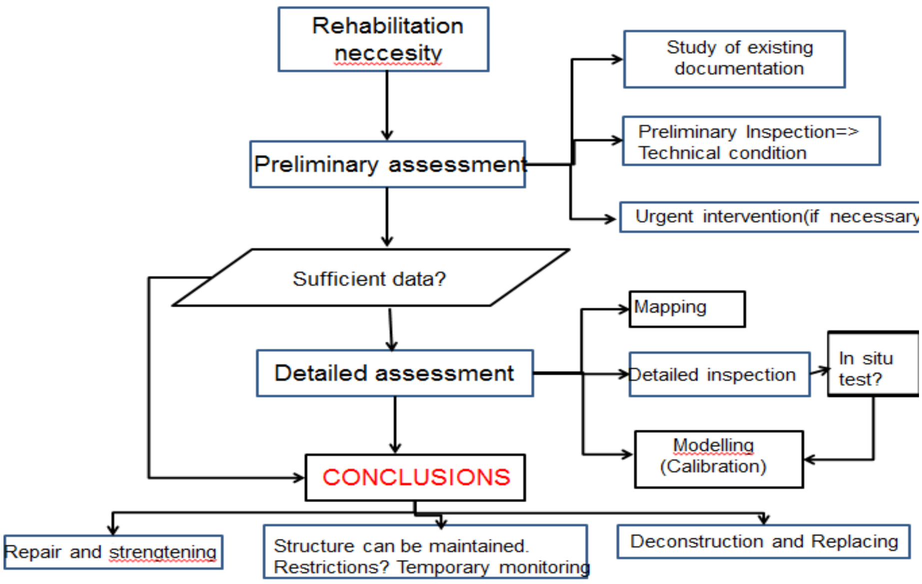


Fig. 1 *Flowchart regarding the rehabilitation of existing structures*

Existing steel structures can be evaluated using the safety concept existing to the time of the structures erection [5], [6] – generally the safety concept of allowable stress.

Nevertheless a checking according to Eurocodes is strongly recommended. For the majority of existing steel structures the documentation is missing. (exception are Railways, they have generally complete archives). In consequence the expert have to do some in situ measurements mapping the structure, which is not always easy, taking into account the accessibility of the structure.

The next step is to perform simple stress verification based on usual calculus methods. These results corroborated the technical condition of the structure, allows to take a decision; the structure can be used in continuation (even with some restrictions), the next evaluation step is necessary, or the structure must be disaffected immediately.

In the second stage a complete verification based on a spatial calculus model are usually performed: In function of the results some reinforcements can be done. It is important to mention that the majority of the structures are riveted; the reinforcement is not simple.

Generally the reinforcement of the structures are not recommended if :

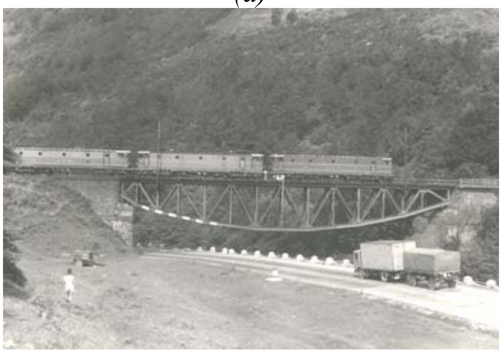
- the additional material is more than 40 % from the weight of the existing structure or 30 % of a new one;
- the cost of the rehabilitation is higher than the cost of a new structure.

Exceptions are the historical structures, monuments of the engineering art; in this situation every situation must be analysed separately.

Reinforcement can be done directly by adding of material (complex by riveted structures), or indirectly by changing the statically scheme (if it's possible), which is more efficient. For usual steel constructions which change their destination (e.g. industrial buildings becoming exhibitions, theatre halls or commercial buildings) the last solution combined with an architectural conception can have as result spectacular end emblematic buildings.

In situ tests of the structure are very relevant, especially for important structure and complicated statically schemes, but there is expensive and time consuming. In situ tests measuring stresses and deformations are used often for existing steel bridges (Fig. 2).

(a)



(b)

Fig. 2 *In situ tests on bridges (a)highway bridge,(b) railway bridge*

Important data about the technical condition of the structure can be obtained and the calculus model can be calibrated (validated). The existence of a Romanian Standard – in this direction – can be mentioned [9].

A special problem in the refurbishment of steel railway and highway bridges is the establishment of the remaining fatigue life. This can be obtained by using simplified methods based on the Miner principle. For example for the Săvârșin bridge, erected in 1897, a total damage of approx.

$$D = \sum n / N = 0,5 < 1,0$$

was calculated. This result gives the possibility to strengthen the structure.

Taking into account the present and future traffic on the bridge, the remaining fatigue life of the structure can be appreciated.

The general affirmation: " *...the bridge is old, consequently the structure is fatigued* " is not correct.

3. Case studies

3.1. Aqueduct Reșița

The Siderurgical Group of enterprises Reşita (founded in 1775) is supplied with cooling water from a distance of 20 km , with open channels excavate in the mountains which surrounds the region, The trace of the channel transverse a valley by open steel aqueduct Reșița erected in 1911 (Fig.3).

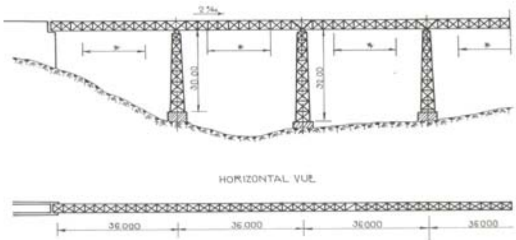


Fig. 3 *Aqueduct Reșița, general view*

It appeared the necessity of the increasing the debit of the cooling water. The solution consisted in raising of the lateral walls with 30 cm (Fig.4); the water debit increased with 15 %. Some strengthening works of the structure where disposed.

In conclusion it was done a sustainable rehabilitation of the structure with a reduced impact on the environment.

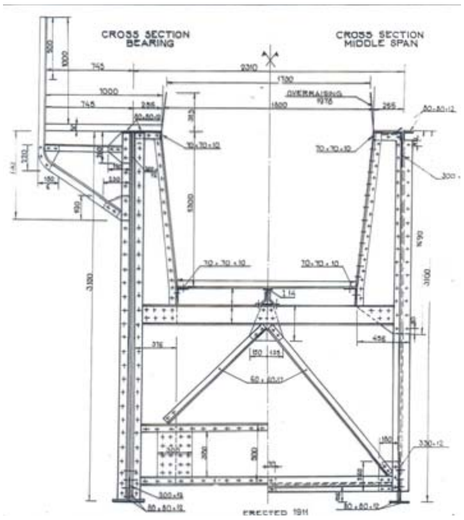


Fig. 4 *Aqueduct Reșița, cross section*

3.2. Săvârşin bridge

The highway bridge in Săvârşin was erected in 1897 (Fig. 5).

The maintenance of the bridge was neglected and the technical condition of the bridge was bad.

Some general principles were taken in consideration: guarantee of structural safety; respect for the cultural value of the structure, minimum intervention, compatibility of the materials and minimum costs.

The rehabilitation of the structure was done with adequate solution without changing the general appearance of the structure. This project received the first European ECCS prize in 2010 [10]. The total reinforcement costs were under 30 % from the costs of a new structure.

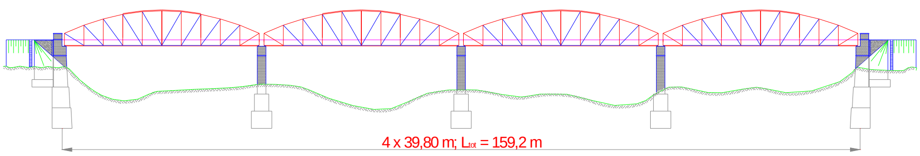


Fig. 5 *General view of the bridge in Săvârșin*

Fig. 6 *Highway bridge in Săvârşin erected in 1897 and rehabilitated after 110 years in 2007*

4. Conclusion

Nowadays the sustainability of steel structures is accepted as a key issue and is essential that the construction industry recognizes the important role it has to play in the environment.

Following the presented cases, the rehabilitation of the steel bridges is a necessity and obligation to be consider, prior to a rebuilding solution.

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