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Analysis of dynamic behaviour under traffic loads of a strengthened old steel bridge

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Summary

The bridge over Mures river situated on the county road DJ 707A at Km. 1+271, near Savarsin, was built in 1897 as a steel structure with four span of 39,8 m. length. All spans were designed in a constructive art typical from historical period of XX-the century begin: the main truss girder with parabolic upper chord and downward cross stud, longitudinal and transverse floor beams (stringers and cross girders) at lower chord, a ZORÉS profiled deck covered by road's system and lower and partially upper wind bracings. In figure 1 is presented the general view of bridge and in figure 2 some pictures of old structure.

Due to the bridge's geometrical dimensions which don't satisfy the present conditions of side clearance it has arranged with road user to assure a single 4,0 m. width running way, which let run also the tractor-allied equipments and farm implements, and two 1,0 m. width pedestrian way near each main girder, separated from running way by a kerb and security sliding carriages.

Inside a co-operation with TU München-Lehrstul für Baumechanik, the proposed strengthened structure has been analysed concerning the dynamic behaviour [2] under traffic loads. The analysis was accomplished with FEM, utilising MSC-NASTRAN program and the simulation with PRESIM 98, an oriented computer program created at TUM, in the aim to simulate the effect of a truck's going over the bridge.

After input data computing has resulted, step by step, the knot's deplacement and stresses in structure elements and after Excel full-automatic processing, it has obtained the diagrams, like in figure 10, which shown, on time dependence, the dynamic effect.

Since both the vehicle and the roadway were idealistically regarded and, no differences were observed.

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1. INTRODUCTION

The bridge over Mures river situated on the county road DJ 707A at Km. 1+271, near Savarsin, was built in 1897 as a steel structure with four span of 39,8 m. length. All spans were designed in a constructive art typical from historical period of XX^{-the} century begin: the main truss girder with parabolic upper chord and downward cross stud, longitudinal and transverse floor beams (stringers and cross girders) at lower chord, a ZORÉS profiled deck covered by road's system and lower and partially upper wind bracings. In figure 1 is presented the general view of bridge and in figure 2 some pictures of old structure.

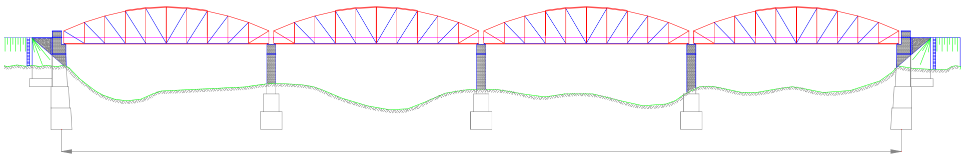

Figure 1. General view of Savarsin bridge

Figure 2. The old bridge structure

2. BRIDGE STRUCTURE'S REHABILITATION

Due to the bridge's geometrical dimensions which don't satisfy the present conditions of side clearance it has arranged with road user to assure a single 4,0 m. width running way, which let run also the tractor-allied equipments and farm implements, and two 1,0 m. width pedestrian way near each main girder, separated from running way by a kerb and security sliding carriages. One-way traffic is regulated by street-traffic lights located at bridge's endings. After a detailed inspection and a design analysis of existing steel structure corroborated with prescriptions of design standards it was adopted different strengthening measures. Our rehabilitation strategy matches the adequate solutions of each structural element [1].

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Bridge's deck rehabilitation. The bad status of roadbed and the strong corrosion of profiled steel deck as well as the great dead weight of bridge covering has contributed to decision of replacement of present deck by a new C20/25 reinforced concrete slab connected with welded head stud from the fresh added flange at upper side of stringers and crossbeams. The old classic way is going to be converted into a composite structure (fig.3 and fig.4) with a relevant elevated bearing capacity and an improved stiffness. In the aim to avoid the weld of connectors on an old riveted steel element, a new weld able flange was attached to stringers and crossbeams using high strength bolts. In the same time the cross girder has been supplementary strengthened by a HEA tie member posted 200 mm. under crossbeam section. A slim profiled steel sheet was used as both formwork and supplementary reinforcement for concrete slab.

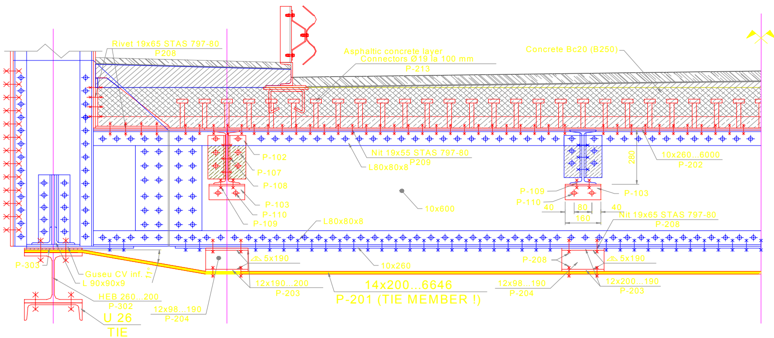

Figure 3. Floor beams cross-section

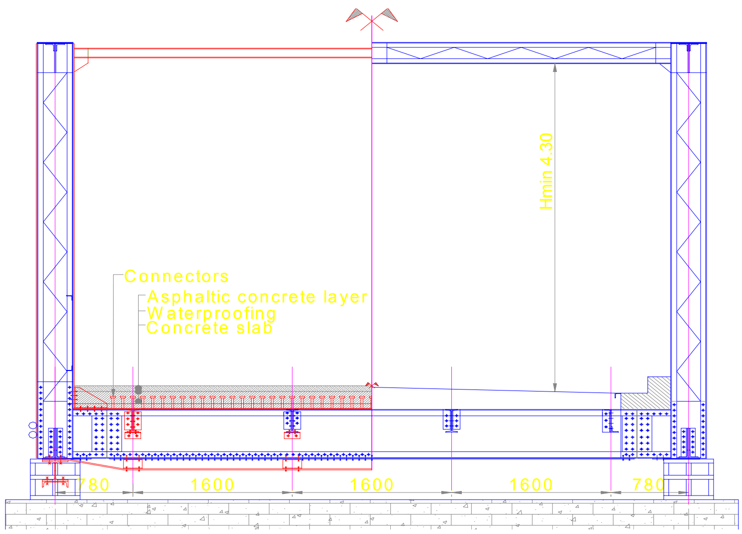

Figure 4. Bridge cross section

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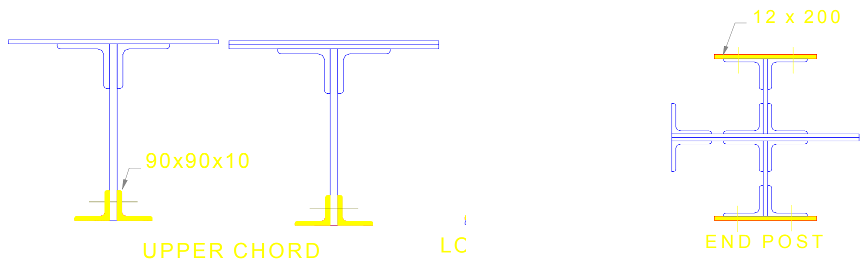
Main girders rehabilitation. For main girders a mixed reinforcing method was applied. That means: a) the direct strengthening of single wall cross-section of upper chord by adding two angle iron so it increase the member's second moment of area and reduce the element slenderness, specially from minor cross-section axis (fig.5a) and the direct strengthening of posts (form brace) by adding new flanges (fig.5b); b) the indirect strengthening by a rigid tie member posted under the bottom chord (fig.4); c) the replacement with new elements of upper wind bracing which has been strongly crooked and damaged by over roadway clearance carriages (e.g. trucks loaded with big saw logs).



a) b)

Figure 5. Reinforcement of main girder members: a) upper chord; b) posts

With this amendments the reinforced structure accomplish the thougness, stability and structural rigidity criteria given in design codes and service regulations.

3. DYNAMIC ANALYSIS OF STRENGTHENED STRUCTURE

Inside a co-operation with TU München-Lehrstul für Baumechanik, the proposed strengthened structure has been analysed concerning the dynamic behaviour [2] under traffic loads. The analysis was accomplished with FEM, utilising MSC-NASTRAN program and the simulation with PRESIM 98, an oriented computer program created at TUM, in the aim to simulate the effect of a truck's going over the bridge. Due to the variety of structure's elements it was utilised in structure modelling different finite elements, such:

a) For the main girder's member, ties member, wind bracing, crossbeam and stringer, the **BEAM-elements** are the dominating elements. This knows normal, torsion and bending general loads transfer (fig.6a.). The Beam-3d element has 6-degrees of freedom in each end and possesses an element matrix of 12×12.

b) The floor slab was simulated by **PLATE elements** (fig.6b). This element is a combined even shell element with a fixed thickness, which does not have to be however over the whole element, but is freely selectable at the corners. It knows

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normal, shearing and bending general load transfer. This element can be modelled also as triangle. The square PLATE element is a very complex element, there it 20 knot degrees of freedom and thus a 20x20-Elementmatrix possesses.

c) The shear connection designed as headed studs used with profiled steel sheeting were simulated by **SOLID-elements** (fig.6c). This element knows normal, bending and thrust general loads transfer. It has 8 knots and possesses as knot free values only shifts. Therefore moment loads can be applied only over auxiliary solutions. The element has only 4 degrees of freedom more and thus a 24x24-Elementmatrix.

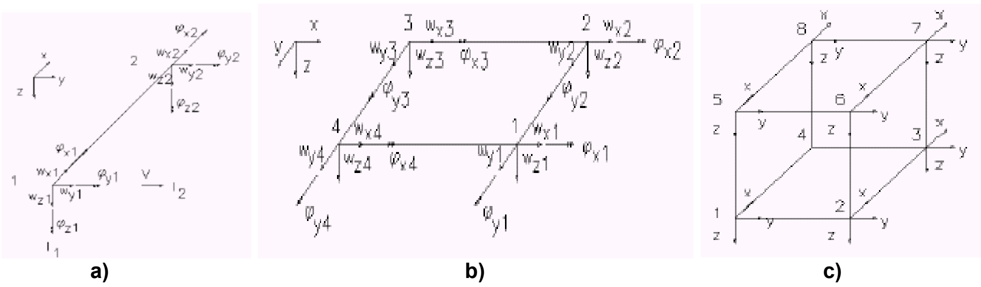

Fig.6. Charachteristic finite elements;

a) Beam element; b) Plate element; c) Solid element.

It was used in bridge modelling about 900 knots and 1286 finite elements. The entire modelled structure is shown in fig.7.

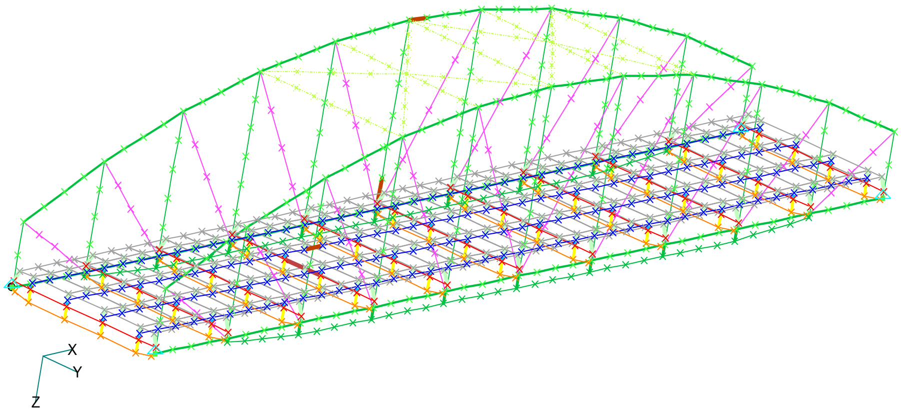

Figure 7. The entire model of reinforced bridge structure

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After CAD analysis of structure's model the first ten eigenmodes and his free-running frequencies have resulted. The normal frequency is 4.2 Hz and this show a stiffened bridge structure (fig.8).

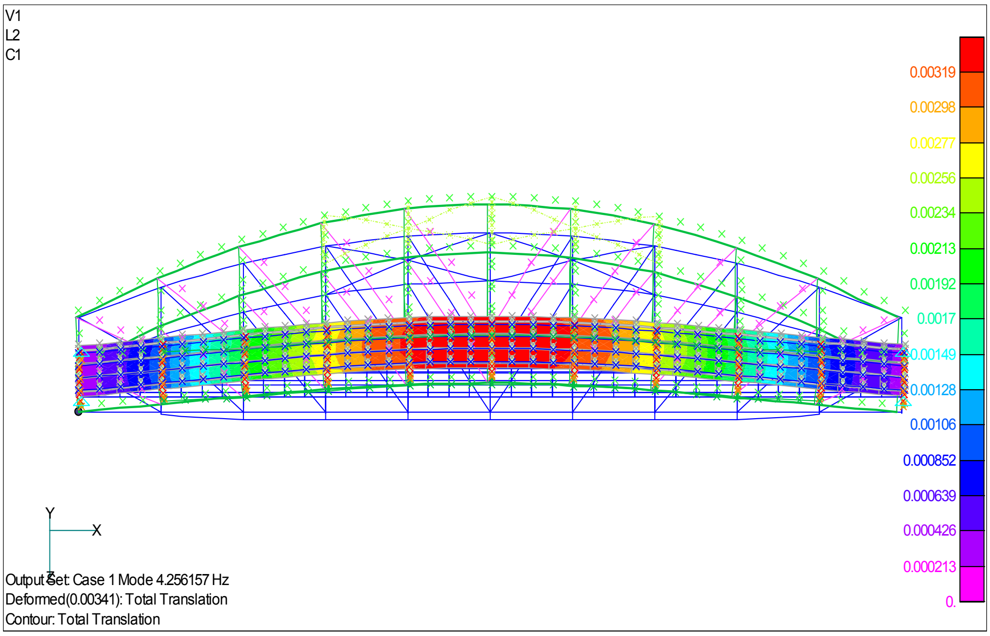

Figure 8. The first eigenmode and corresponding frequency

4. THE TRUCK'S PASSAGE SIMULATION

For the computation of passages of the different vehicle models out over the bridge model a pre-processor with the designation **"PRESIM 98"**, developed at TU Munich, has been used. In the context of their theses Fritsch (1994) [4], Lichte (1996), Neun (1998) and others [3],[5] already argued with the interaction and developed a pre-processor, that the conversion of the algorithm on Nastran input code automated. Bridge construction work and the vehicle is mechanically representable by its rigidity and mass matrix. If both models become directly in NASTRAN (and/or FEMAP) produced, then the stencils are built up automatically and the only problem for the users remains to model that material building and/or material vehicle suitably.

The well known linear equation from the building dynamics reads:

$$[\,M\,]\,\{\Phi''\} + [\,C\,]\,\{\Phi'\} + [\,K\,]\{\Phi\} = \{P\} \qquad (1)$$

whereby M the mass matrix, K the rigidity matrix, Φ the vector of the knot degrees of freedom and P the load vector. NASTRAN uses the symbol "s" as a time derivative operator, whereby (1) are also written as:

$$[\,Ms^2 + Cs + K\,]\ \{\Phi\} = \{P\} \qquad (1.a)$$

Interaction simulation with PRESIM 98, FEMAP and NASTRAN.

Vehicle and bridge should be produced first in two separated files. PRESIM 98 can process spatial vehicle models with maximally 8 axles. We have regarded an **A30** vehicle model after Romanian standards. For the input in PRESIM 98 the knot numbers of the left and right wheel trace as well as their distance from bridge beginning are to be noted to. Also it is necessary as input data the running way roughness. For the Savarsin bridge have no measured roughness, thus counted the interaction simulation on an ideal carriageway slab and the result will represent the corresponding influence line. In order to together-drive vehicle and bridge model in a file, bridge model (e.g. bruecke.mod) must be loaded first into FEMAP and then the vehicle model (e.g. truck.dat) to be read in. This vehicle-bridge system should be stored under its own file name (e.g. sys.dat).

Static and dynamic passage simulation. The toes of the vehicle moves per time step a certain amount on the bridge-broad. This shift is however under normal conditions smaller than the modelled knot distances of the bridge. This has the consequence that the load is applied on the 2 edge knots of this element, because it is not possible an element between the knots to load. With it, like one is crucial this distribution of load assumes.

In the dynamic effect simulation two representative truck's running speeds were considered: a reduced one of 1 m/s (about 3,6 km/h) which represent the static loading and a higher one, of 14 m/s (about 50 km/h) which represent the speed of normal traffic over bridge as dynamic loading so it is shown in figure 9

i) static passage v = 1 m/s (3,6 km/h)

initial loading	intermediately loading	end loading
t = 0 seconds.	ti = (0,1.... 36,9) seconds.	t = **47** seconds.

Computed intermediate load conditions $\Delta L = 0.1$m and $\Delta t = ti_{+1} - ti = 0{,}1$ seconds.

ii) dynamic passage v = 14 m/s (50 km/h)

initial loading	intermediately loading	end loading
t = 0 seconds.	ti = (0,1.... 3,25) seconds.	t = **3,35** seconds.

Computed intermediate load conditions $\Delta L = 0.1$m and $\Delta t = ti_{+1} - ti = 0{,}00712$ sec.

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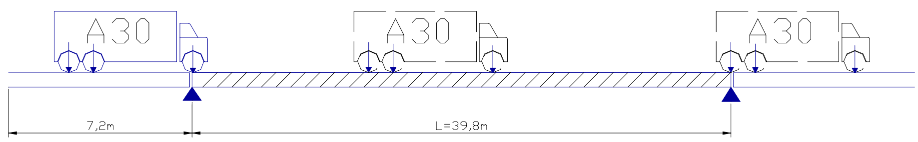
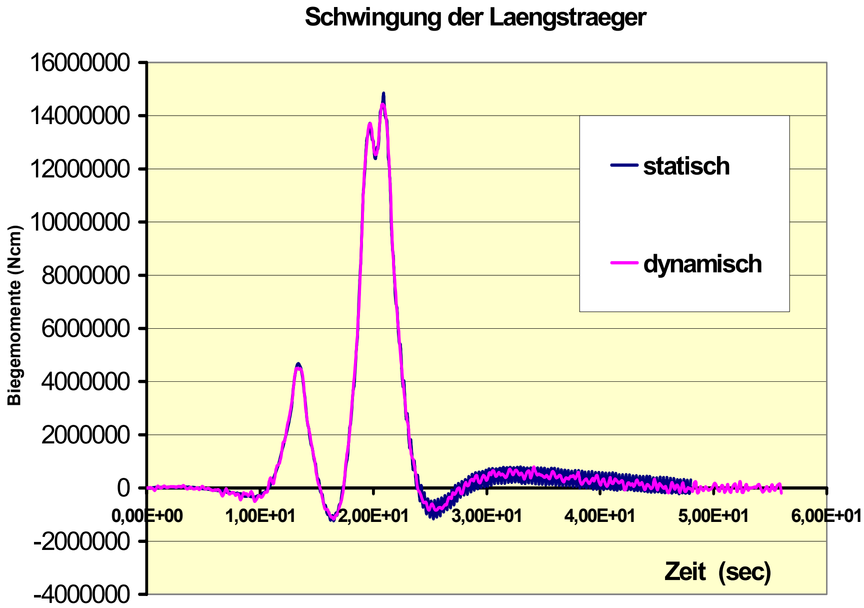


Figure. 9. Run travel of the A30-truck over the bridge

5. CONCLUSIONS

After input data computing has resulted, step by step, the knot's deplacement and stresses in structure elements and after Excel full-automatic processing, it has obtained the diagrams, like in figure 10, which shown, on time dependence, the dynamic effect.

Since both the vehicle and the roadway were idealistically regarded and, no differences were observed.



Figure

10. The dynamic effect of stringer

Additional analyses are recommended for the future with considering also:

roadway imperfections those experimentally measured knew;

truck natural oscillations.

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