STRUCTURAL HEALTH MONITORING WITH ADVANCED NONDESTRUCTIVE METHODS BASED ON WAVELET ANALYSIS

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Abstract. Steel structures, especially if they are exposed to the demanding loading or environmental conditions, need to be monitored concerning the actual in-service properties. For reliable monitoring it is important to know the initial properties in order to diagnose possible degradation with time. The target result of the presented research is to develop and apply the procedure for the degradation identification. The obtained results would serve as input for the model analysis that enables estimation of the structure condition and to support decision on the maintenance activities.

In the experimental part of the presented research the model of the steel bridge was made to analyze the anomalous structural behavior and to optimize the selection of the appropriate monitoring methods. Various static and dynamic loads have been utilized on the model, with intentionally inserted steel structure failures (e.g. cracked bar, loosened screw joint). The structural responses are very well suited for the wavelet transforms and related wavelet analysis. This paper presents the procedure to correlate results of the wavelet analysis with the inflicted failures within the structure.

1. Introduction

Reliable and safe behavior of the structures is desire of the end user. Material ageing, environmental affects, damages, etc, are affecting the durability, reliability and safety of structures. Structural integrity monitoring (SIM) is a necessity to know and foresee the condition of the structure [1]. The system degradation affects the time-frequency characteristics of the system's response. [2].

It would be useful to determine the possible location of the structural damage with the method which evaluates structure in general and if possible with the excitation which is already present at the object under observation, i.e. truck moving over the bridge, wind acting on the tower or building, [2].

Analysis of the response could be presented in the time and/or frequency domain. Analysis in the frequency domain has some shortcuts since the time of certain event occurrence is not known. To overcome this deficiency the wavelet transform can be used in order to provide information in the time and frequency domain. To analyze the suitability of the classical FFT approach and of the wavelet analysis to characterize dynamical behavior of the structure with some induced damages in the elements, we performed analysis on the model of the steel space truss bridge. Firstly the responses were calculated and then compared to the experimental values.

2. Numerical analysis of the problem

We were applying the analysis on the real 3D bridge model, which is presented on Fig. 1 [4]. Structure is space truss, assembled by two longitudinal truss frames of the 3600 mm in length, divided on 8 sectors of the 450 mm in length. Height of the frames is 440 mm, and width is 360 mm. Upper compression loaded and lower tensile loaded elements are made of cold formed elements HOP U30/30/2 mm, verticals are made of HOP U 30/20/2 mm, and diagonals are assembled from two HOP U15/30/2 mm and from two HOP L20/20/2 mm (Figs. 2 and 3). Upper compression loaded elements are connected by the HOP U 50/25/3 mm and centrically connection is made of round bars ø 6 mm. Lower tensile loaded elements are in the location of the supports connected with the HOP U 30/20/2 mm. For the numerical modeling the quality of the material S235 with the modulus of elasticity E = 210 GPa was used.

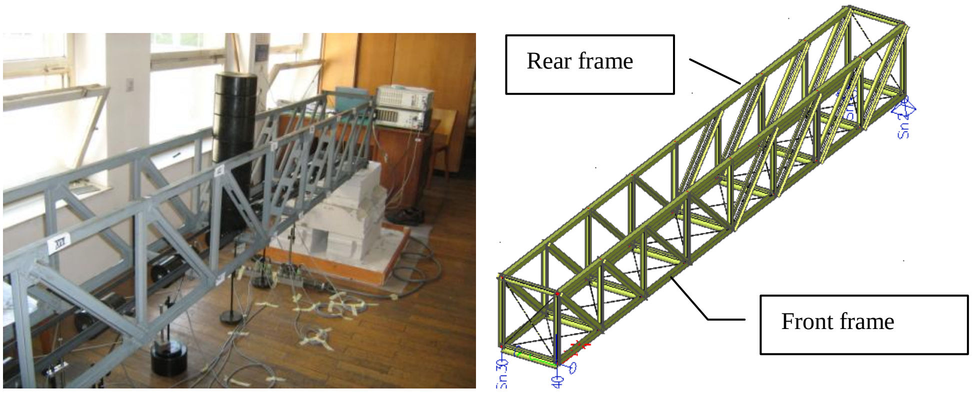

Figure 1: a) Laboratory bridge model b) 3D FE bridge model.

In the model the rigid connection are assumed since the joins are made with the rigid bolted connections. In the model the sliding moment free supports were used.

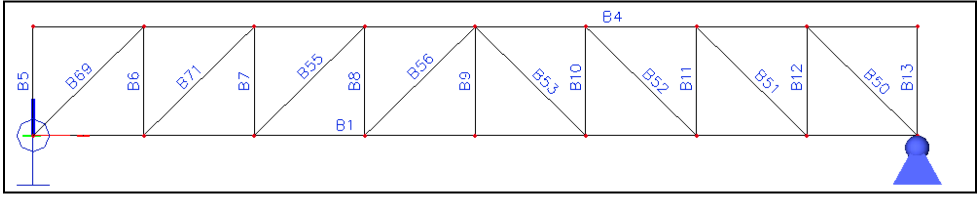

Figure 2: Elements of the front frame.

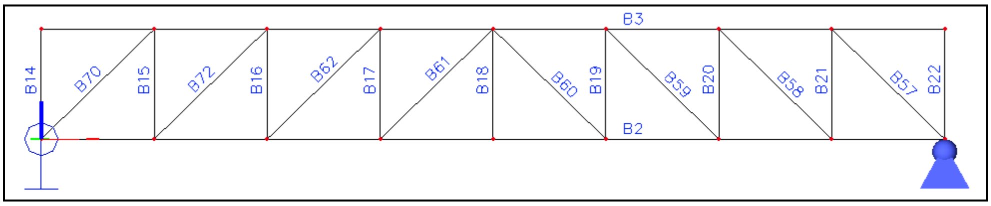

Figure 3: Elements of the rear frame.

Dynamic analysis, i.e. eigenfrequencies and modes of vibrations were calculated for the loading case presented on Fig.1 (57N on all joints at the bottom of the front and rear frame).

The analysis of the dynamic behavior of a structure was performed for cases where some of the diagonal elements in the structure were eliminated. Since diagonals are assembled of two L elements one was removed, i.e. rigidity of the diagonal was reduced to one half. Location of removed elements and calculated first natural frequencies for individual cases are presented in table 1.

Table 1: 1st natural frequencies for different “damage” cases

Case	**Removed element**	**1st eigenfrequency [Hz]**
0	none	43,27
I	B69	43,01
II	B69 + B70	42,74
III	B71	43,12
IV	B71 + B72	42,96
V	B71 + B72 + B69	42,71
VI	B69 + B70 + B71 + B72	42,45
XIV	B69+B70+B50+B57+B71+B72+B51+B58	41,71

Even in the case when more than half diagonals have reduced stiffness to one half, the frequency is not changed significantly. From this numerical analysis we can conclude that conclusions on the possible structural damage based on the measurements of the global structure first natural frequency could be misleading. Even if the change of the cycle time would be determined, it would not be necessary the consequence of the rigidity change but could be caused by the temperature change.

3. Experimental analysis

On the model of the bridge measurements were performed for the case 0 (no-loose) and I (loose) from the table 1. Accelerometer was positioned on the middle of the bridge in vertical direction. The sampling rate was 5 kHZ and loading was induced with the sudden release of the 100N from the middle of the bridge model. Response is for both cases presented on Fig. 4. The 1st natural frequencies determined by the FFT are 41,7 and 41,2 Hz for the case 0 and I respectively.

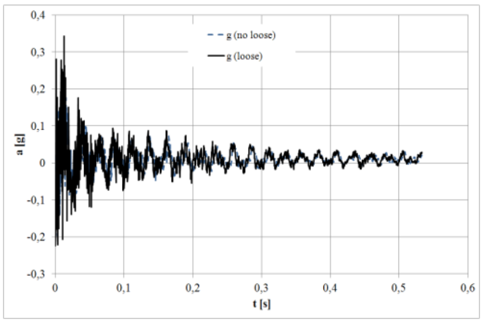

Figure 4: Measured response of the bridge model.

Since the conclusion based on the time domain and FFT analysis is the same as conclusion based on numerical analysis we performed the wavelet analysis. We applied Daubechies 3 kernels [4] and significant differences can be observed on the wavelet coefficient as presented for the third level coefficients on Fig. 5.

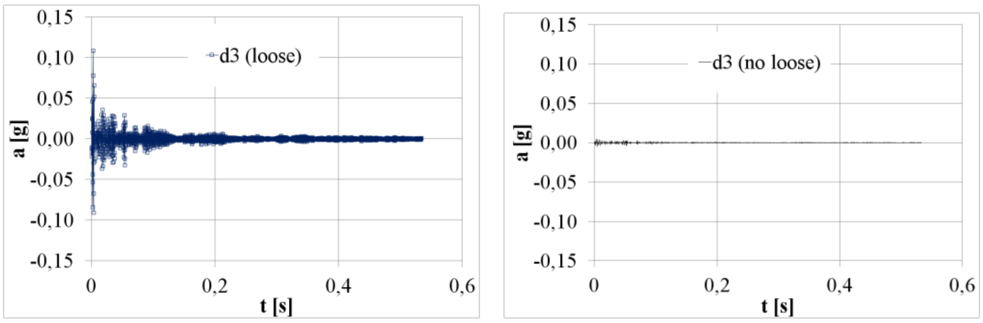

Figure 5: Wavelet coefficient on third level.

5. Conclusion

On the space truss bridge model comparison of the un-damaged and damaged bridge response to the sudden load was performed. With the analysis in the time domain and with the FFT we can conclude that conclusions on the possible structural damage based on the measurements of the global structure first natural frequency could be misleading. Wavelet analysis enables to distinguish the differences in the responses.

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6. References

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