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Structural Integrity Assessment by Using Cross-Correlated Modal Identification

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Abstract

Early researches on steel structures integrity were mainly oriented on calculations and conventional experiments. Robust numerical methods of a high accuracy are usually less reliable in estimation of dynamic properties and a true condition of a steel structure. On the other hand, experiments on real structures, being in regular operation, could be very demanding to conduct. Therefore, the implementation and justification of novel methodology in structural integrity analysis is presented here. The main idea is to correlate experimental results with those obtained applying ANSYS software package. Throughout a results cross-correlation and model adjustment the new presentation of the structure is created, involving natural frequency, modal mass, stiffness and damping. By a proper definition of those parameters, and a 3D model of the structure, a preliminary map of measuring points and measuring configuration are set in order to enable structural integrity assessment. Example of application of this procedure is given.

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Keywords: Structural, integrity, assessment

1. Introduction

Very few papers deal with detection of machine induced vibration of steel structures due to the complexity of the problem. In order to solve it, researches were mainly oriented on calculations by the finite element method (FEM) and conventional experiments, including measurements on site. In this paper experimental results are compared with those obtained applying ANSYS software package. Using results of cross-correlation and model adjustment, steel structure model is created, involving natural frequency, modal mass, stiffness and damping. By a proper definition of those

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parameters, and a 3D model of the structure, a preliminary map of measuring points and measuring configuration are set in order to enable structural integrity assessment. Example of application of this procedure is given as a true case study of increased vibration in a floor in power plant. Essentially there are two possible sources of excessive vibrations, [1,2]:

- Resonance of the floor structure triggered by surrounding machinery (turbines, generators, pumps, mills...).
- A transfer of excessive vibrations from the surrounding machinery throughout the floor structure without resonance.

2. Experimental measurement

The control room floor is a rebar concrete plate on a grillage steel structure, consisting of welded steel bars (cross section I 400), and 12 m high steel columns (rectangular cross section, 50 mm wall thickness, [1,2]).

Two 8-channel acquisition devices are deployed for the site measurements. Complete data files from the acquisition devices are delivered to a laptop computer serving as a data collector. Measurement on site was carried out by Wilcoxson Instruments 780A piezoelectric accelerometers. Temperature rating (–50 to +120°C) suits the temperature in the zone of measurement (50°C). Sensor sensitivity 100 mV/g is well adjusted for the intended measurements as well its natural frequency, around 25 kHz. According to the outcome of the FE modal analysis, the floor structure natural frequency is around 13 Hz, and the highest spectral component on the pipeline is around 750 Hz. This frequency is far enough from the accelerometer natural frequency.

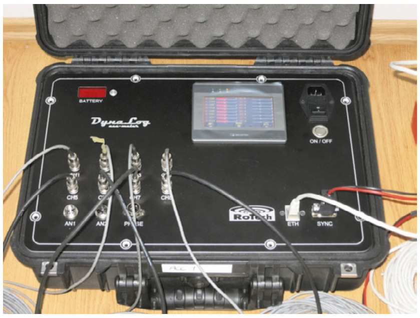

Figure 1. Acquisition device

An arrangement of 16 measuring points is established, 8 located on the top side of the floor and 8 below the concrete plate, Figure 2. The whole data set is analysed in Matlab. In order to detect the prominent spectral components, the Fast Fourier Transformation (FFT), is applied, as shown in Figure 3 as an example.

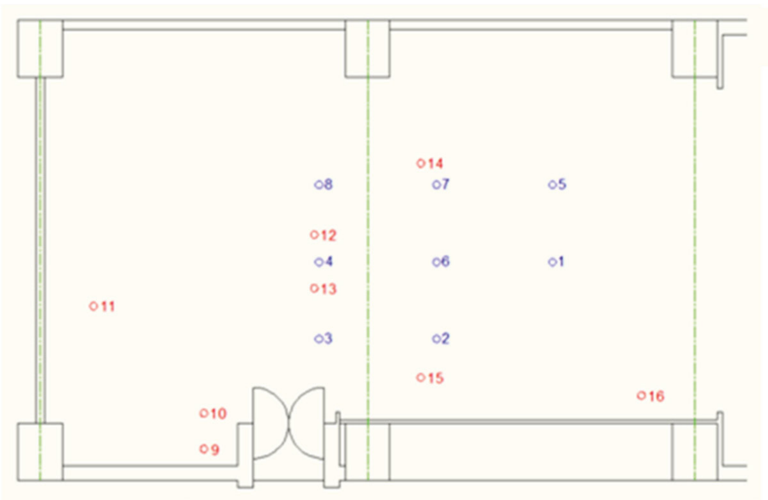

Figure 2. Disposition of the measurement points (blue-above, red-below concrete floor)

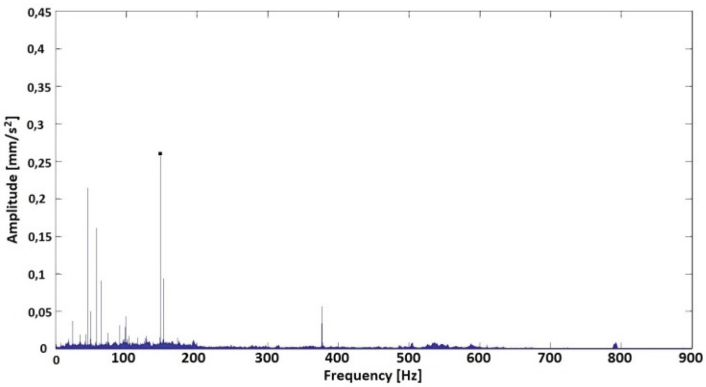

Figure 3. Collected data in frequency domain (CH4).

3. Finite element simulation

The finite element model is shown in Figure 4 obtained by the ‘sweep’ method, resulting in the finite element mesh with 2722 elements and 2324 nodes. Intensive vibrations at the measurement point CH4 are recognized as a part of second mode shape (shown in Figure 5). Harmonic response analysis for frequency range 0-900 Hz, with a step of 0.25 Hz, provided result as shown in Figure 6.

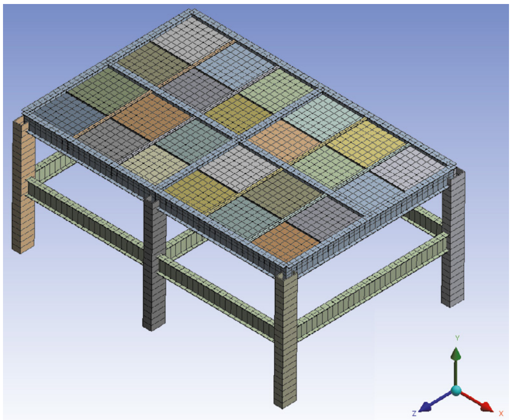

Figure 4. Sweep method FE mesh of 3D model.

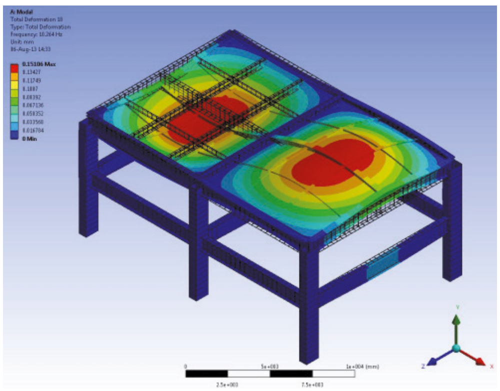

Figure 5. Mode shape of the second natural frequency.

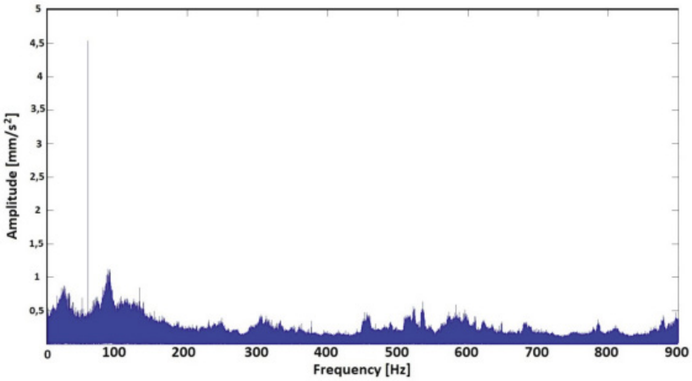

Figure 6. Excitation at the measurement point CH12

Measurement results show the presence of vibrations at 58 Hz, which is very close to one of the natural frequencies of the structure (63 Hz). The difference is approximately 10 %. It is reasonable to conclude that it is not a resonance, but a simple transfer of excitation vibrations. The same frequency component (58 Hz) exists on channel CH12 (Figure 6). If it were the resonant frequency of the concrete slab, a component of 58 Hz would have been dominant at all response measurement points, which has not been the case. It is dominant only at measurement point CH4 (Figure 3) that is physically close to the attaching point of the excitation sling CH12 (as could be seen in the Figure 2).

Conclusions

The analysis of the FE simulation and the full-scale site measurement defined the characteristics of the excitation on the pipeline and the response of the floor. Cross correlated analysis directed the conclusion towards the vibration in the control room to be a pure reflection of dynamic excitation, produced by two distinct pipelines.

The testing methodology described briefly here, has been justified on several steel structures, and this work has approved its universality.

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