The choice of boundary conditions and mesh for scaffold FEM model on the basis of natural vibrations measurements

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Abstract

The paper presents procedure for a choice of selected parameters of a scaffold FEM model. The main aim of analysis is the best projection of the real construction. Different boundary conditions are considered, because of their impact on construction vibrations. Natural vibrations obtained from FEM calculations are compared with free vibrations measurements performed during in-situ tests.

Keywords: scaffold, free vibrations, numerical model, FEM, full-scale measurements

1. Introduction

One of issues connected with the use of scaffolds is their susceptibility to low frequency vibrations. Employees walking on the scaffold are one of the main sources that can cause construction vibrations. The numerical model which correctly represents the real construction and its dynamic behaviour is needed to analyse workers walking on the scaffold. Preparation of the FEM model is a difficult task because of the specific character of the construction. The paper presents FEM model information, procedure of choosing boundary conditions and model verification on the basis of free vibrations in-situ tests.

2. Model description

2.1. Real construction data

Figure 1 presents Plettac SL 70 frame scaffolding. The width is 0.74 m, total length is 21.0 m and the height is 9.0 m.

Figure 1: The scaffold view

Working decks are made of two wooden platforms with the exception of consoles, where aluminum platforms are used. Primary elements of construction are: frames, bracings, guardrails, anchors and working decks.

2.2. Preliminary scaffold FEM model

The scaffold model was made in Autodesk Simulation Mechanical software (Fig. 2). The scaffold construction was modelled as the system of beam elements. Working decks were modelled as plate elements pivoted on pins fixed to the transoms of frames. Bracings, guardrails and toe-boards were beam elements with joints at their ends. Pivot supports between structure and ground and fixed supports in the façade of the building were considered in preliminary calculations. Masses of elements in the model were adjusted to real masses by proper selection of material densities.

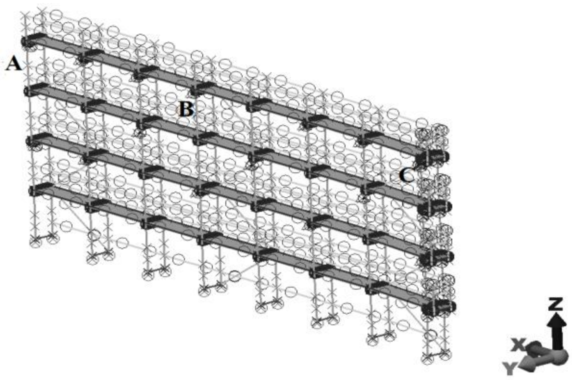

Figure 2: Scaffold FEM model

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3. Identification of dynamic parameters on the basis of in-situ tests

Measurements of vibration accelerations performed on the scaffold allow identification of construction free vibrations. Exciting forces were applied in three points (in two extreme frames, left and right – A and C and in central frame – B) at the 3rd working level. Brüel & Kjær Pulse analyser and a set of four accelerometers were used in tests. Measurement points were located under the highest working level. Two triaxial accelerometers were mounted to scaffold extreme frames, whereas two uniaxial accelerometers were attached to the middle frame. Triaxial sensors registered accelerations in two horizontal directions (x, y) and vertical direction (z), whereas uniaxial sensors measured accelerations only in two horizontal directions (x, y).

FFT analysis was made on accelerations waveforms [1]. Natural vibrations frequency was based on obtained diagrams. The exemplary accelerations waveform is presented in Figure 3. The first natural frequency which appeared in this test was equal to 2.5 Hz (Fig. 4).

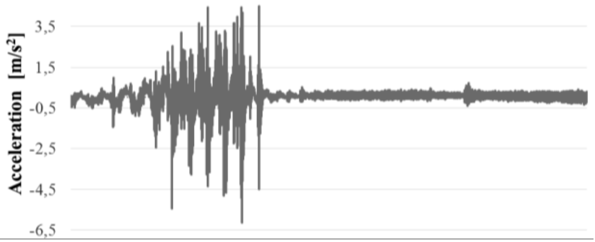

Figure 3: Examplary accelerations waveform

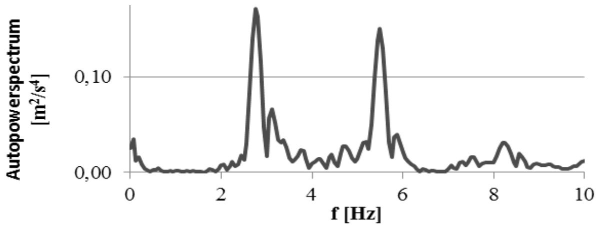

Figure 4: Power spectral density of accelerations

4. Verification of scaffold FEM model

At the initial stage two models were considered – model with the ideal geometry (I) and with the deformed one (II). Imperfections were received from geodetic measurements of the real construction. Vibrations excitation was realized by 100 kg person. Calculations without additional mass (0) and with additional mass located respectively in points A, B and C were carried out. Construction supports used in the model at the initial stage are described in pt. 2.2.

The 1st natural frequency near 2.5 Hz did not appear in calculations. Due to discrepancy of results, the FEM model was changed to model III. It has free transition in direction along the scaffold (x) in ground supports where frames have connections with bracings. Both: imperfections and change of supports cause decrease of the 1st natural frequency value (Fig. 5).

Scaffold anchors are often not fixed properly at the building wall what have the influence on construction vibrations. The change of supports in façade of the building was assumed in the next step of analysis. The connections between anchors and wall were modelled by different sets of fixed and pinned connections. After consideration, model IV was chosen as a representative one. Model IV was based on model III, but the anchors at the 3rd and 4th working levels and every second anchor at the 2nd working level had joint connections in the façade of the building. The 1st natural frequency value was 2.4 Hz and this result was considered as satisfactory when compared to the value of 2.5 Hz from in-situ tests. Results of analysis are presented in Figure 5.

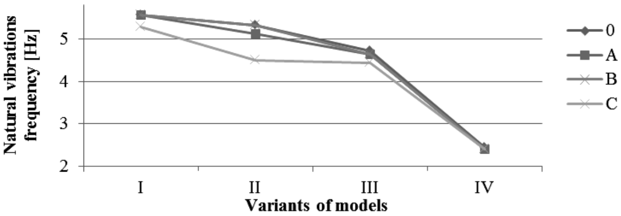

Figure 5: 1st natural vibration frequency in dependence on the location of additional mass

The influence of density division of elements as well as one hundred increase of pins stiffness was also considered during model verification. The additional following models were analysed: V – model IV with the denser division of elements, VI – model IV with one hundred increase of pins stiffness, VII – model IV with denser division of elements and one hundred increase of pins stiffness. Figure 6 presents results of these calculations.

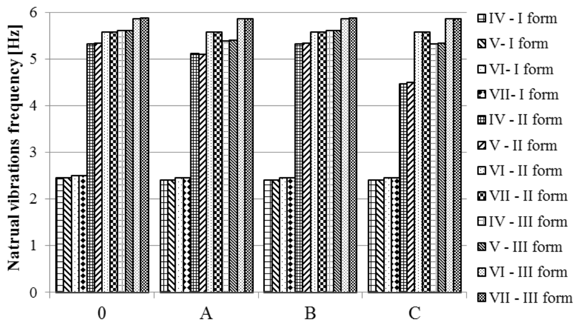

Figure 6: Comparison of natural vibrations frequencies for variants IV–VII

According to the results shown in Figure 6 it can be said, that denser division of beam elements does not have impact on the natural vibrations frequency of the scaffold model. Influence of increase of pins stiffness is negligible in case of the 1st frequency of vibrations, in the 2nd and 3rd is slightly bigger, but also insignificant.

5. Conclusions

Presented results showed, that it is significant to take into consideration real imperfections of the construction and that anchors should be modelled as joint connections. Free transition in direction along the scaffold in selected ground supports and modification of boundary conditions of anchors have the greatest influence on changes of natural vibrations frequency values. The obtained scaffold model can be used for analysis of the dynamic problems considering excitation forces produced by workers walking along decks.

References

[1] Broch, J. T., *Mechanical Vibration and Shock Measurements*, available from Bruel & Kjaer Instruments, Inc., Marlborough, MA, Oct. 1980.