Dynamic wind action on façade scaffoldings

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Abstract

Paper presents an approach to evaluation of the dynamic wind action on scaffolding structures. Wind field, random in space and time, was simulated using Weighted Amplitude Wave Superposition method. FEM model of the scaffolding was created on the basis of geodetic measurements and verified by in-situ dynamic measurements of vibrations. Wind forces were applied to the nodes of the FEM model in every connection between stands in outer plane of the scaffolding. Direct integration was used as the solution method. The time-dependent response of the structures was determined.

Keywords: FEM, wind action, wind field, scaffolding, simulation of stochastic process

1. Introduction

Wind load is one of the main loads for temporary structures such as façade scaffoldings. There is not much information in literature on the real wind action on scaffolding structures. Only a few papers deals with the wind action measured in wind tunnels [f.e. 1,2]. The majority of papers are related to accidents or laboratory tests on strength of the elements. According to authors' knowledge there were no attempts to simulate wind action numerically.

This paper deals with the numerical approach to the wind action on scaffolding. The stochastic wind speed field was generated in chosen points of the structure. The wind load was calculated on the basis of the wind speed and applied to the nodes of the FEM model of scaffolding.

2. FEM model of the scaffolding

The scaffolding was located in Ostrzeszów by the new constructed residential building in the built-up terrain. It consisted of 6 rows of stands and 6 levels of decks. The considered façade was located on the east-north side of the building. Figure 1 presents the structure and its surroundings. The building façade had no openings and there was no cladding on the scaffolding during measurements.

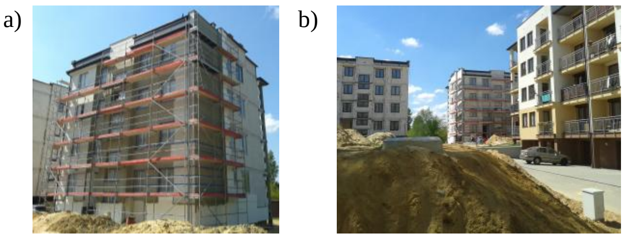

Figure 1: Façade scaffolding: a) view, b) surroundings

The scaffolding was investigated in-situ, and among others the geodetic measurements of the real shape of the structure were performed. Therefore, created FEM model of the scaffolding structure exactly reflected its real dimensions.

Boundary conditions used in the FEM model were assumed on the basis of in-situ observations and FEM modal analysis. Results of the modal analysis, such as mode shapes and frequencies, were compared to those measured in the real scale.

Joint supports were assumed in anchorages. The supports at the left and the right edge of the scaffolding (which modelled connection with other structure) were set as flexible in two directions. Fixed supports allowing movement along the scaffolding were used under base jacks. Additional masses of the total value of 3.24 kN, distributed equally among four connections with other façades scaffoldings were added at both edges of the structure.

The model was verified on the basis of measured frequencies of vibrations and axial forces in chosen stands.

Decks were made of wood with the thickness of 4.4 cm. There were no ledgers and transoms in the FEM model of the deck but bolts were modelled in order to hang the decks to the frame transoms.

The FEM model of the whole structure and its part with boundary conditions are shown in Figure 2.

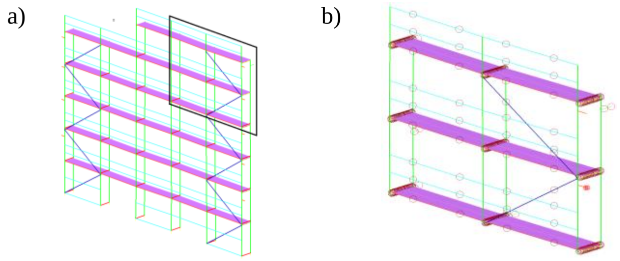

Figure 2: FEM model: a) overall view, b) details

3. Wind field simulation

Wind is a space-time stochastic process. It is quite challenging to get wind field with proper characteristics in numerical simulations. The knowledge about wind field can be obtained from full-scale or wind tunnel measurements or CFD simulations. As it is presented in this paper, stochastic processes simulation methods could be a good alternative to CFD in terms of getting proper wind field.

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The following assumption was made – the wind field was generated for undisturbed flow – terrain category was considered but not changes of the flow caused by neighbouring buildings. This assumption seems to be valid when the results are related to the ones obtained according to code recommendations.

A few locations on the structure (8 points) were chosen as the simulation points (Figure 3). The following main features of the simulation were assumed: a) von Karman spectrum of the wind speed; b) power-law vertical wind profile; c) built-up terrain; d) Weighted Amplitude Wave Superposition method as the simulation method; e) mean wind speed on 10 m – 22 m/s; f) time step – 0.01 s; g) number of time steps – 8192.

The wind field was generated in chosen points, and as results all three components of the wind speed were obtained (*u*, *v*, *w* – corresponding to *y*, *x*, *z* of the global system, comp. Figure 5).

Three components of aerodynamic forces were calculated according to the sample relation:

$$F_y = 0.5\rho u^2 \cdot c_f \cdot A \tag{1}$$

where: ρ – air density, $0.5\rho u^2$ – pressure of the wind speed, c_f – aerodynamic coefficient, A – the area exposed to the wind.

Since it was assumed that the same load is acting in the vicinity of the simulation point it was also applied to the neighbouring nodes of the FEM model (Figure 3). In every FEM node the respective force was calculated taking into account values of A and c_f. In total, 102 curves of time varying forces were applied to 34 nodes of the model. The nodes were chosen in the outer plane of the scaffolding in connection between stands of consecutive levels. The time-dependent wind speed components simulated in point 7 and the wind forces in node 412 (2nd top from the left) are presented in Figure 4.

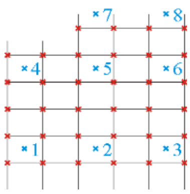

Figure 3: The location of simulation points and nodes of the FEM model

a) b)

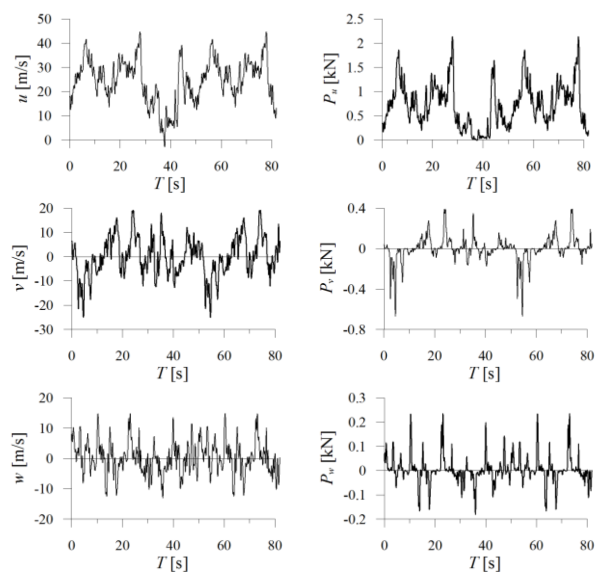

Figure 4: a) Wind speed components in point 7, b) wind forces in node 412 of the FEM model

4. Dynamic wind action on scaffolding

Direct integration was used in the dynamic analysis. Mass-stiffness damping was included according to the relation:

$$\mathbf{C} = \alpha \cdot \mathbf{M} + \beta \cdot \mathbf{K} \tag{2}$$

where: **C**, **M**, **K** are damping, mass and stiffness matrixes, α, β – damping parameters calculated on the basis of the logarithmic decrement of damping δ and circular frequencies of vibrations ω_1 and ω_2. Damping was estimated from in-situ measurements of accelerations made in several points of the scaffolding. Frequencies ware calculated for the verified FEM model. The example of the deformation of whole scaffolding is presented in Figure 5 whereas time histories of displacements in chosen nodes in Figure 6.

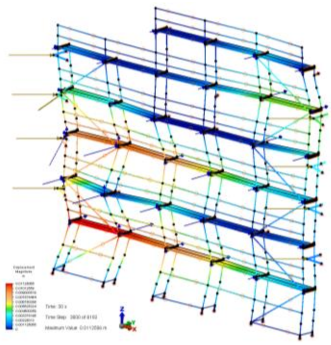

Figure 5: Deformation of the structure at t = 30 s

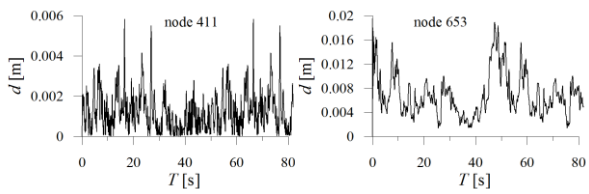

Figure 6: Time history of displacements: node 411 – 6th level of decks, node 653 – 3rd level of decks, 3rd stand from the left

5. Conclusions

The paper presents FEM calculations of the scaffolding response to the dynamic wind action. FEM model was built on the basis of geodetic measurements of the structure and verified on the basis of in-situ observations and measurements of free vibrations. The stochastic processes simulation method was used to generate wind field Dynamic analysis of the structure indicates that: 1) displacements of nodes are relatively low, with maximum about 2 cm, 2) normal stresses in beam elements and von Mises stresses in decks are much lower than limits. The approach will be verified by in-situ measurements of the wind action with use of sonic anemometers. In this case the real wind action affected by building vicinity will be considered. Results will be also compared with ones obtained from calculations made according to code recommendations.

References

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