FINITE ELEMENTS METHOD IN ANALYSIS OF PROPAGATION OF VIBRATIONS WAVE IN THE SOIL

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Abstract

Nowadays, many residential buildings are built in areas close to railway and tram lines. Therefore, there is a necessity to find a method that allows taking into account in the process of building design influences of the vibration caused by passing trains and trams. This article presents analysis of propagation of vibration wave excited by the movement of trams in the soil on which is planned to build multi-storey residential building. To determine the amplitude of vibration the Finite Element Method (FEM) model was used. The FEM model which was used during the analysis takes into account variable heterogeneous mechanical properties of the soil. The analysis uses the results of measurements of vibration acceleration amplitudes done by employees of the Department of Robotics and Mechatronics AGH during the works on government research project 4875/B/TO2/2010/38 and the results of drilling carried out to identify the composition of the soil at the planned place of foundation building. The developed method allows determining the wave vibration in the ground without necessity to perform complex measurements of soil vibration. The proposed method can be successfully applied in the preparation of project documentation for public buildings and reduces the costs of preliminary analysis of the influence of the traffic on the dynamic properties of the newly designed facility.

Keywords: *Finite Element Method, building design, vibration analysis, railway transport, building vibration isolation*

1. Introduction

This article presents analysis of propagation of vibration wave excited by the movement of trams in the soil on which is planned to build multi-storey residential building. To determine the amplitude of vibration the finite element method (FEM) was used. The analysis uses the results of measurements of vibration acceleration amplitudes done by employees of the Department of Robotics and Mechatronics AGH during the works on government research project 4875/B/TO2/2010/38 and the results of drilling carried out to identify the composition of the soil at the planned place of foundation building.

2. Description of the fem model

Computational model consists of a cuboid with dimensions of 30x19x4 m which was built with the following elements:

- UIC60 tracks were modelled with beam elements with rectangular cross-section.
- Railway ties PS-83 were modelled with eight-node solid elements in a 670 mm scale.
- Stony ballast of 300 mm thickness below the railways ties was modelled with four-node solid elements. Between the ballast and the tracks there was no contact.
- Subgrade of 300 mm thickness was modelled with four-node solid elements.
- Soil was modelled with four-node solid elements.
- Sidewalk of 50 mm thickness was modelled with four-node solid elements.
- A fragment of the building was modelled with four-node solid elements.

Computational model was located along the III measurement line (Fig.1).

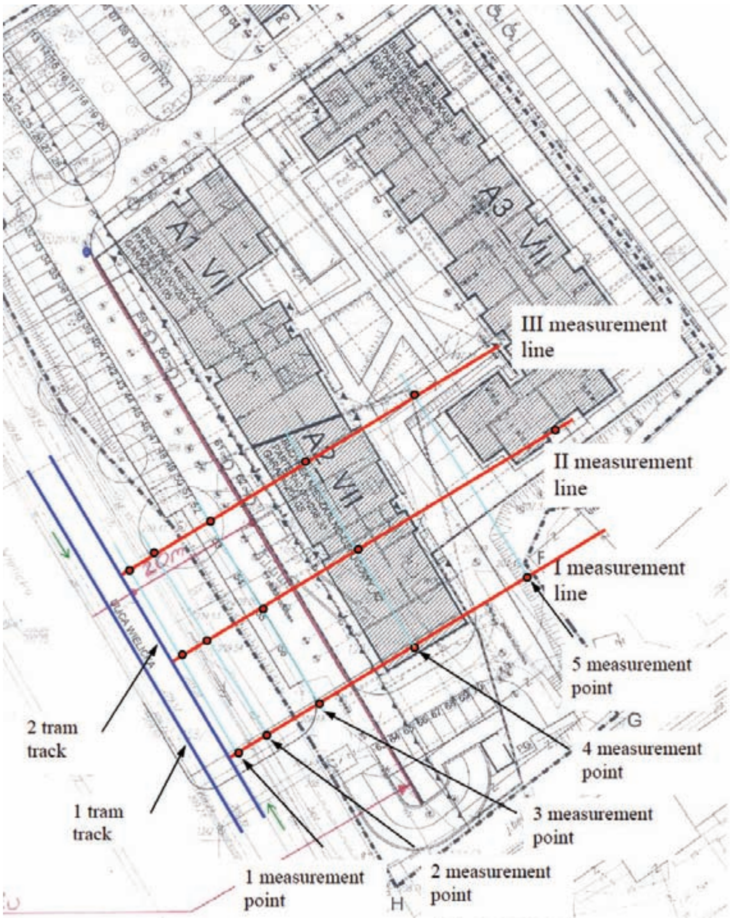

Fig. 1. Location of measuring points used in carried out analysis

3. Finite element model of the soil

In order to simulate the propagation of vibration wave in the soil the computational model was built (Fig. 2). Based on this model the finite element model of the soil was built (Fig. 3). For this model all of the analysis of the propagation of vibration wave in the soil was performed [1].

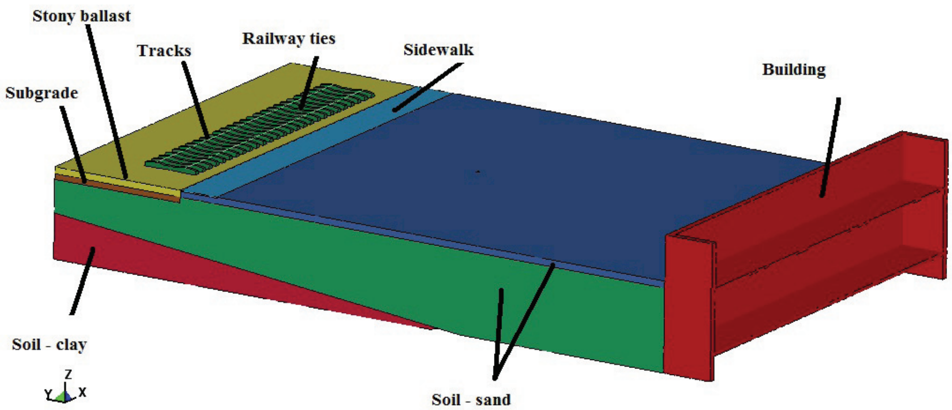

Fig. 2. Diagram of computational model

Table 1 summarizes the most important properties of FEM model components material. These data have been taken from available literature and from the results of drilling carried out to identify the composition of the soil at the planned place of foundation building.

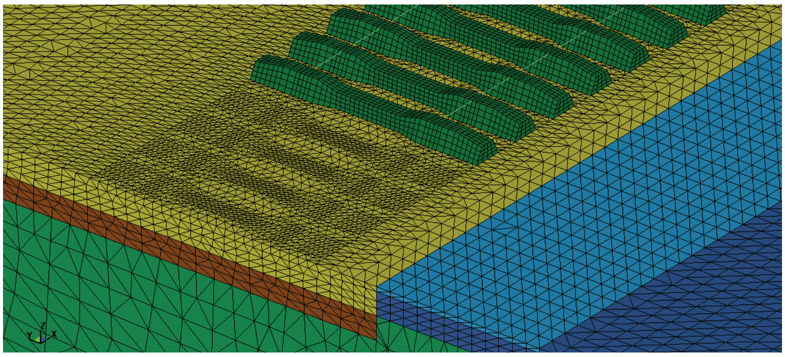

Fig. 3. FEM model used in the analysis

Tab .1 Material properties of FEM model components

	UIC60 tracks - steel	PS-83 railway ties - prestressed concrete
Density [t/mm^3]	7.86E-09	2.55E-9
Viscous damping coefficient	0.02	0.05
Poisson's ratio	0.3	0.3
Young's modulus [MPa]	2.10E+05	47500
	Stony ballast	Subgrade - sand
Density [t/mm^3]	2.20E-09	2.05E-09
Viscous damping coefficient	0.05	0.05
Poisson's ratio	0.35	0.3
Young's modulus [MPa]	4900	70
	Sidewalk – asphalt	Soil – sand
Density [t/mm^3]	2.50E-09	2.05E-09
Viscous damping coefficient	0.04	0.05
Poisson's ratio	0.3	0.3
Young's modulus [MPa]	28000	70
	Soil – clay	
Density [t/mm^3]	2.3E-09	
Viscous damping coefficient	0.05	
Poisson's ratio	0.32	
Young's modulus [MPa]	47	

The model was restrained by special boundary conditions which are not reflective waves, reaching the boundaries of the model [1, 2]. These conditions allow limiting the size of a computational model and are very often use for modelling of the earth [3]. These special boundary conditions were applied for all surfaces that are cut-off limit of the model taking into account from the environment including the fragment of the building (Fig. 4).

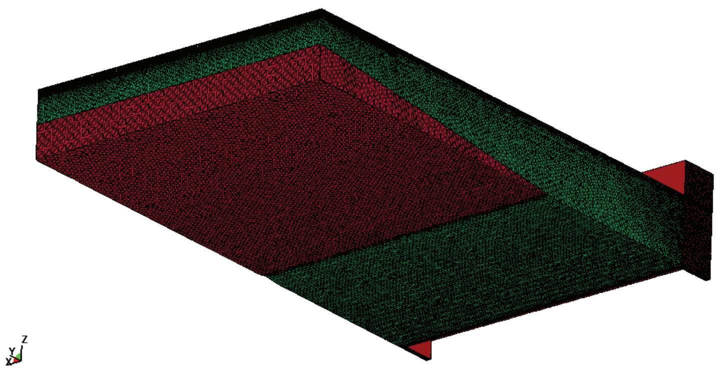

Fig. 4. Boundary conditions of FEM model

The analysis of wave propagation in the soil was performed for Bombardier NGT-6 tram which is the most critical case due to the highest allowable axle load 10t. For this tram the bogie wheelbase is 1800 mm. The simulations involved a single tram bogie passing through the finite element model of the soil. During the analysis we simulate the tram ride through finite element model with maximum speed 45/h (12.5 mm/s). Therefore, the load model which was prepared corresponds to the transit of single bogie by one section of tracks. The force was applied to the track nodes with a triangular characteristic of the amplitude and duration appropriate to model a single truck passing at speed of 12.5 mm/s. The amplitude of load varied from zero to maximum value and then again to zero for the mapping of a single bogie ride and because of the stability of numerical analysis (Fig. 5).

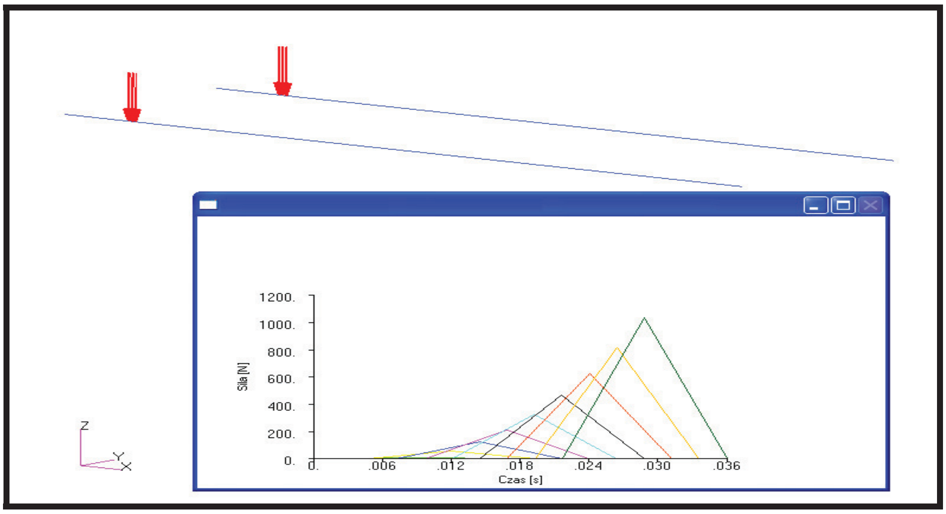

Fig. 5. Example of the amplitude of force for several track nodes

Load characteristics of a single node are shown in Fig. 6.

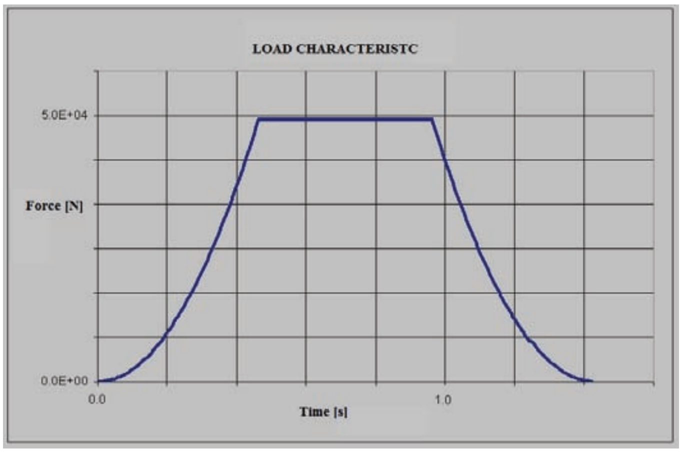

Fig.6. The value of the maximum amplitude of the load as a function of time

4. Results of vibration propagation in soil

Results of the analysis are presented as graphs of acceleration amplitude in two directions (X, Y). Simulation points 1, 2, 3 correspond to the measurement points 1, 2, 3 in the third measurement line (Fig. 7).

Figure 8 shows the graph of the amplitude of vibration acceleration of soil vibrations at the measuring point 2 obtained from simulations, Fig. 9 - shows the graph of the amplitude of vibration acceleration of soil vibrations measured during the experiment.

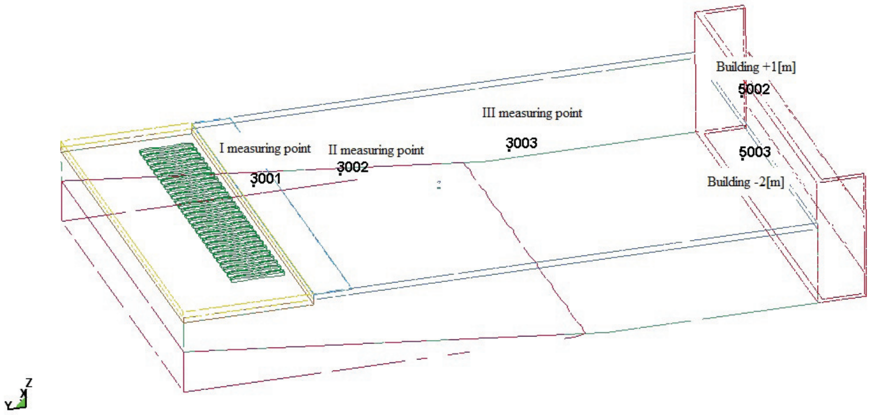

Fig. 7. Location of measuring points at the FEM model

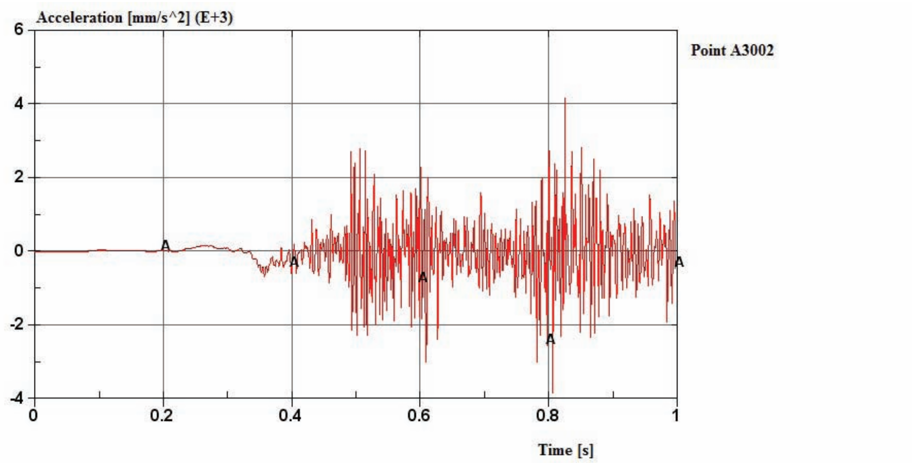

Fig. 8. Amplitude of vibration acceleration of soil vibrations at the measuring point 2 obtained from simulations

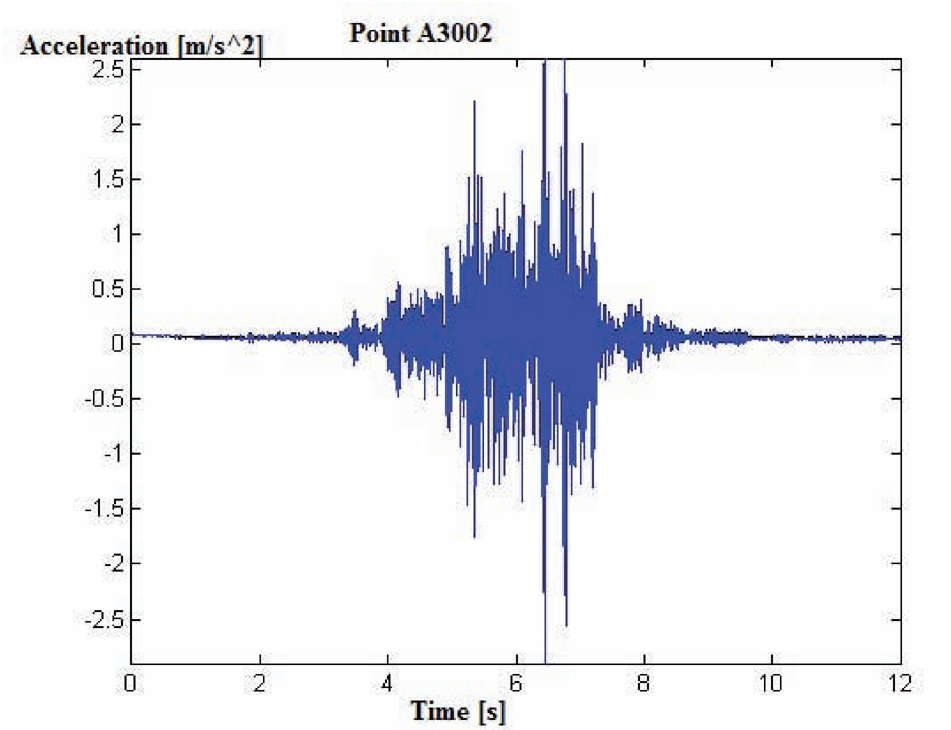

Fig. 9. Amplitude of vibration acceleration of soil vibrations at the measuring point 2 measured during the experiment

By comparing these two waveforms (from simulation and measurements) can be stated that the FEM model used study the propagation of vibrations in the soil is correct. Vibration acceleration amplitudes are similar. The same results are obtained for vibration analysis made in the other measuring points, the other measuring lines and other directions of vibration (axis X, Y). Slightly differences are caused by heterogeneous mechanical properties of the soil which are variable and affect significantly the measurement results.

In addition, a simulation of the foundation vibration of newly designed building was carried. The results of this analysis for points lying in the third measuring line and located at the foundation of 1 m above the ground and 2 m below the ground surface in the direction of X and Y axes are shown in Fig. 10 and 11.

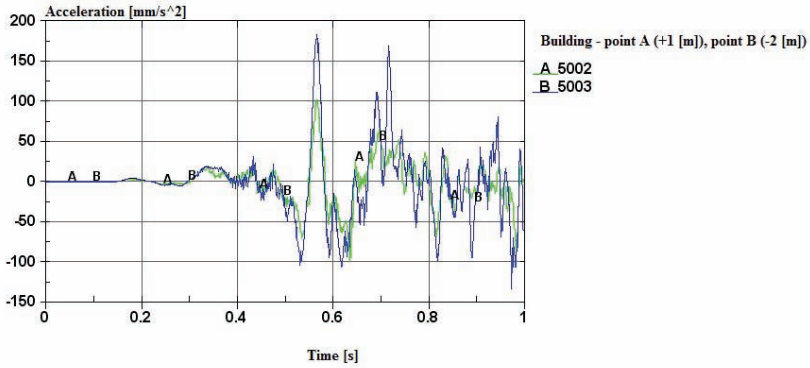

Fig. 10. Amplitude of the vibration acceleration of the foundation of the building in the X direction

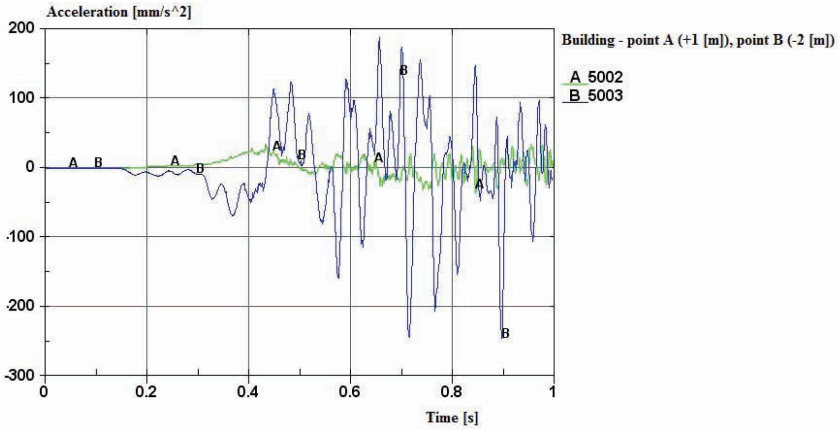

Fig. 11. Amplitude of the vibration acceleration of the foundation of the building in the Y direction

The results (Fig. 10 and 11) can be concluded that the amplitude of vibration acceleration in X and Y axes exceed the limit values. The simulation results showed that the amplitudes of vibration acceleration of foundations of newly designed buildings that exceed the value of 0.005g and the propagation of vibration wave should be take into account during the design process of building.

5. Conclusions

Analysis results clearly show that acceleration amplitudes of ground vibrations caused by trams traffic in the area where is planned to built a multi-storey residential building repeatedly exceed the values allowed by Polish standard PN-85/B-02170 "Evaluation of the harmfulness of vibrations transmitted through the substrate on the buildings" [4]. Construction of a residential building in this place is a risky venture and requires consideration in design its inertial forces. There also possibility to consider at the design stage to include other technical means to limit the dynamic effects of railway transport (tram), such as:

- exchange and strengthen of the land (piling)
- land drainage and outpouring of the bottom slab,
- increase weight of the garages foundation to the level of soil strength,
- vibration isolation of buildings in the so-called bowl,
- modern vibration isolation of tram tracks,
- limit a speed of train to 20 km/h over a distance of about 50 m,
- set sunken vertical screen with a width of 30 cm with which bottom should be below the foundations of the building.

The above-mentioned technical measures, however, require significant financial effort and a considerable extension of the design and construction of planned residential building.

References

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