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INFLUENCE OF LOADING IS FROM A ROLLING STOCK ON THE DYNAMIC BEHAVIOR OF MULTI-STOREY BUILDING

The investigation of the rolling stock load influence on the multi-storey building being under construction in the close to the railroad area has been conducted. FEM calculation models of the ballast prism and the building in the interaction with the base soil were created. The acceleration of the soil at the depth of the foundation laying was obtained and, as the result, its influence on the dynamic behavior of building was evaluated.

Keywords: finite element model, dynamics, a rolling stock, multi-storey building, vibrations, ground acceleration.

Problems of vibration of the soil are becoming increasingly important in densely populated areas. This contributes to the development of transport infrastructure in areas with high population density. Railways within the big city transports heavy trains with dangerous goods at high speed through densely built-up areas. In addition to the constant threat of environmental emergency situations, it creates noise and strong vibration in the close to the railway houses. Rolling stock is the source of wave propagation in the soil, affecting the design and construction of residential buildings near the railroad tracks. Vibration can cause uneven settling of foundations and additional stresses in the elements of frame buildings, which causes cracks and even destruction. Low-frequency waves and waves that are close to the natural frequencies of buildings make the greatest influence on vibrations of buildings structures that are located near the railway.

Despite the fact that a lot of effort is devoted to the research of seismic effects on structures, aspects of vibration caused by traffic remain poorly understood. There is no credible data today on how the vibrations that occur when tre rolling stock goes spread on the ground.

Fluctuations in railway wheels and crews are determined by a complex interaction of contact forces, geometrics, spring suspension systems, crew weight and damping coefficients. All this makes the task very interesting. Even when driving on a straight path at low speed there are problems associated with wagging fluctuations. There are significant fluctuations in vertical or twisting motion in the form of forced transverse vibration of the wheelsets that appear at high speed. The nature of the dynamic interaction between train and railway varies depending on operating conditions, the nature of the principal areas of the roadbed, inequalities of wheels and rails, as well as climatic conditions.

Building a universal mathematical model to fully take into account all aspects of the interaction of the rolling stock and railway is still an impossible task. But using simplified models may explore complex dynamic phenomena that are consequences of these interactions in a particular field of research. In the research of vertical vibrations through identity excitations in the left and right wheels of a single wheelset, the design scheme can be reduced to a flat one. Wherein cart frame and wheelset frame are considered as rigid bodies with their mass concentrated in the center of mass.

The loads acting on the rail consist of vertical and horizontal longitudinal and transverse forces. Determination of loads that the rolling stock transfers to the rail and parameters of the stress-strain state of the upper part of the way is performed by generally accepted methods [1-4].

The task includes the creation of a model of interaction of the building with a ground base and interaction of the rolling stock and ground. Currently, there are several possible accounting of the elastic properties of soil base. The easiest way - Winkler foundation model, which can be implemented using the finite element linear elastic single-point connection. The main drawback of the Winkler model is that it ignores the distributing properties of the soil. An alternative to using the Winkler foundation model is a model of an elastic half-space. In this case, the base is modeled by a set of volumetric finite elements, the properties of which depend on the depth of the overlying layer. The obvious disadvantage of this model is a significant increase in the size of the model.

Assessing the influence of the dynamic load of the rolling stock on the behavior of multi-storey building has been completed in two phases. The aim of a first step was to investigate the dynamic characteristics of the soil together with the ballast prism through which the load is transmitted from the rolling stock. The second stage investigated the stress-strain state of the building from the effects of kinematic excitation of ground defined in the first stage. By the means of NASTRAN complex the finite element model of ballast and soil in the form of a flat elastic-plastic half-space has been built.

The finite element model of ballast prism and base is created (fig. 1).

Soil of the base is considered as a flat elastic half-space. Taking into account the elastic-plastic response of the soil according to the formulas $E_0 = E/(1-\nu^2)$, $\nu_0 = \frac{\nu}{(1-\nu)}$ calculations are made for the following physical characteristics of the base and ballast:

sand (base): $E_0 = 16,484 \cdot 10^3 kPa$, $\nu_0 = 0,429$, $\beta = 0,32$, $\rho = 18,0 kN/m^3$;
sand (ballast): $E = 25 \cdot 10^3 kPa$, $\nu = 0,3$, $\beta = 0,3$, $\rho = 10,0 kN/m^3$;
aggregate (ballast): $E = 5 \cdot 10^5 kPa$, $\nu = 0,27$, $\beta = 0,27$, $\rho = 14,0 kN/m^3$;
reinforced concrete sleepers: $E = 3,8 \cdot 10^7 kPa$, $\nu = 0,2$, $\beta = 0,05$, $\rho = 24,5 kN/m^3$.

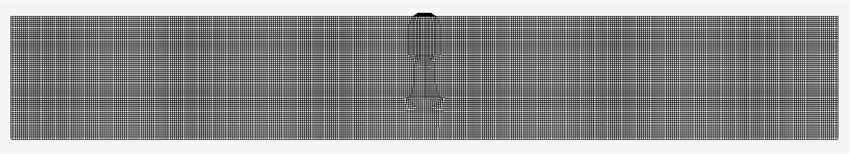


Fig. 1. The calculation chart – finite element model of ballast prism and basis

In this work there is a research of the dynamic behavior of frame building under construction in the the hundred meter zone of tracks. The house has eight above ground and one underground floor (fig. 2). The maximum plan dimensions of the building are $11 \times 36\, m$ (fig. 3). Height of the building is $27,1\, m$. Constructive scheme is a braced frame structure. Monolithic reinforced concrete raft on the basis of root piles is taken as a foundation. Overlapping and coverage slabs are monolithic flat. Partitions are made of bricks and concrete blocks. Pylons, stiffness diaphragm and lift shafts are made of in-site reinforced concrete.

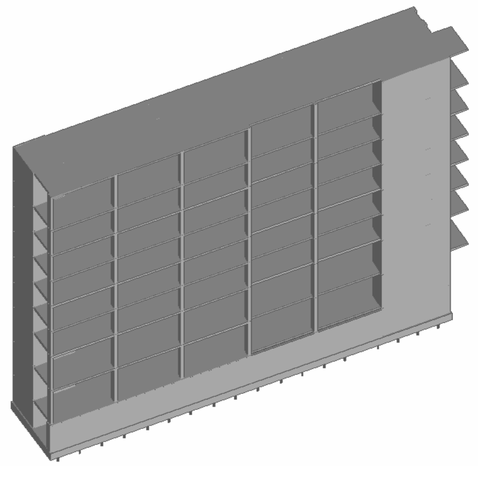


Fig. 2. 3-D model of the building

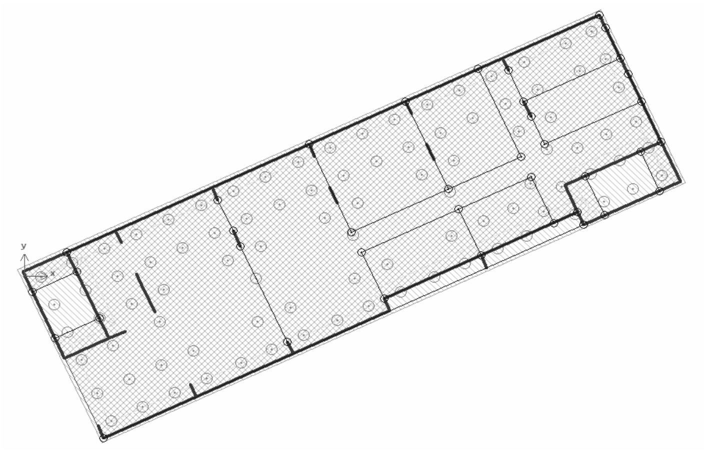
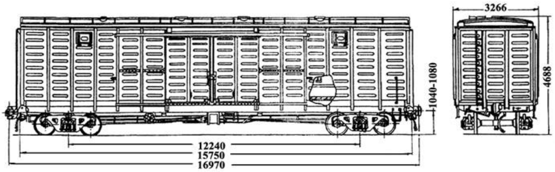


Fig. 3. Foundation plan and circuit cellar

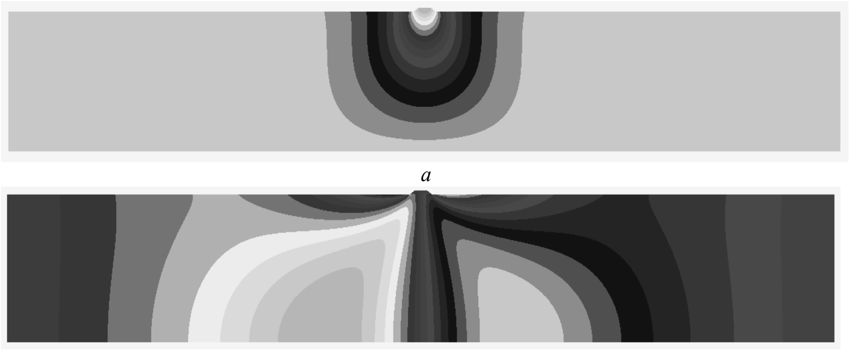


Purpose: for transportation of piece, grain and other goods of a wide range, requiring protection

Project Number	260.00.000-00
Specifications	TU24 - 5 - 498- 86
Carrying capacity of	67 tonnes
Wagon tare weight of	26 tonnes
load: static axial	228 *kN*
Design speed of	120 *km/h*
Base car	12240 *mm*
Length: over coupler pulling faces	16970 *mm*
end girders of the frame (frame length)	15750 *mm*
Maximum width	3266 *mm*
Height from top of rail head: maximum	4688 *mm*
up to floor level	1286 *mm*
Number of axles	4 pcs.

Fig. 4. Model specifications 11-260

First of all, a linear static calculation basis for the action of vertical load as a concentrated force of 230,5kN has been performed. This gives us the isofields of vertical and horizontal displacements (the maximum is 0.0536m) (fig. 5), normal and equivalent stress of model.



a

b

Fig. 5. Isofields of: a) vertical displacements; b) horizontal displacements

To perform dynamic analysis of the base the modal analysis using Lanczos method was conducted taking into account the 10 forms and frequencies of natural vibration.

Fig. 6 presented the first 6 forms of natural vibrations basics. It is seen that there are a kososymetrycal (1, 3, 5) and symmetrical forms (2, 4, 6).

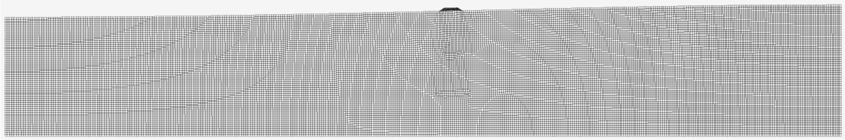
Eigenfrequencies constitute: ν=[0,2374;0,4605;0,6297;0,8042;0,8219] *Hz*.

The dynamic calculation of the base is executed under the action of vertical periodical load caused by the movement of the car with a load of 228,0*kN*; natural vibration frequency of the car was 6,046sec^{-1}. The calculation is made by direct numerical integration of the motion equation at the first natural frequency of 0.237372*Hz* (transition process t = 5*sec*). The transition process includes both own harmonic vibration of the model at the first frequency and influence of periodic load from carriage with goods. The maximum displacement of loading point is 0.0357 *m* at time t = 0,45 *sec*. Accordingly, the dynamic response factor is: 0.0536*m*/0.0357*m* = 0.67 *m*. If v = 40 *km/h* the passage of one car (L = 19.2 *m*) is t = 1.73*sec*, if v = 100 *km/h* – t = 0.19 *sec*.

The characteristics of the soil were investigated at a distance [0 – 100]*m* from the action of the vertical load in the static and dynamic performances. The nonlinear problem is solved by the Newton-Raphson method of phase-static loading. Dynamic task of determining the eigenfrequencies and mode shapes of the model was performed using Lanczos method. Ground motion together with the ballast under the influence of the vertical load, which is modeled as a periodic load with a frequency equal to the eigenfrequency of the vertical oscillations of the freight car were investigated. The task of forced vibration is solved by direct numerical integration of differential motion equations of the Runge-Kutta method of order 4. Building of a finite element model of the building and its modal analysis was performed in the software package SCAD.

The quasi-static method was applied for determining the stress-strain state of the building from the ground kinematic excitation represented as vectors of accelerations applied along the entire height of the building foundation.

Mode 1



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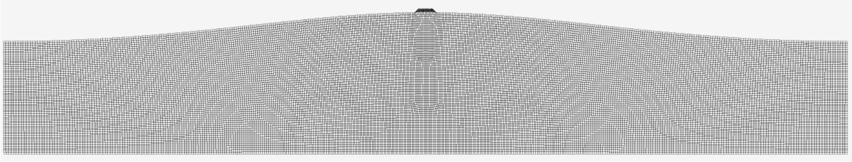

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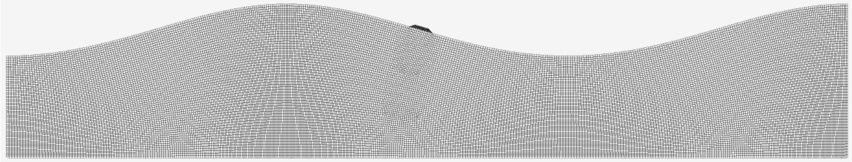

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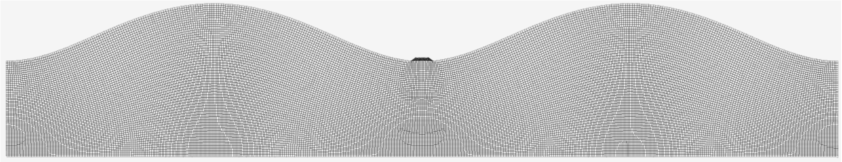

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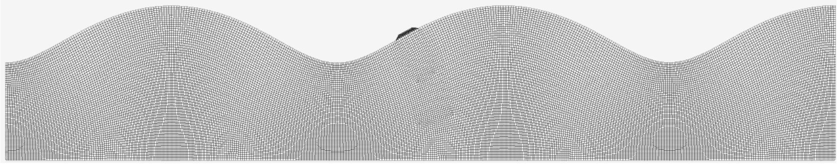

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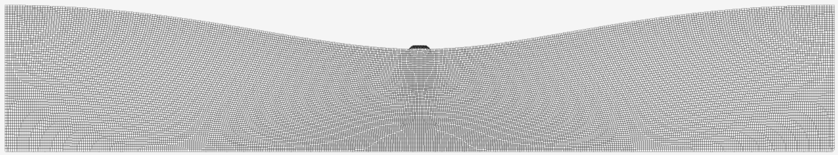


Fig. 6. Forms of natural vibrations

Consider the dynamic behavior of the surface layer of soil at a distance of [0 – 50]m from the action of vertical load (fig. 7).

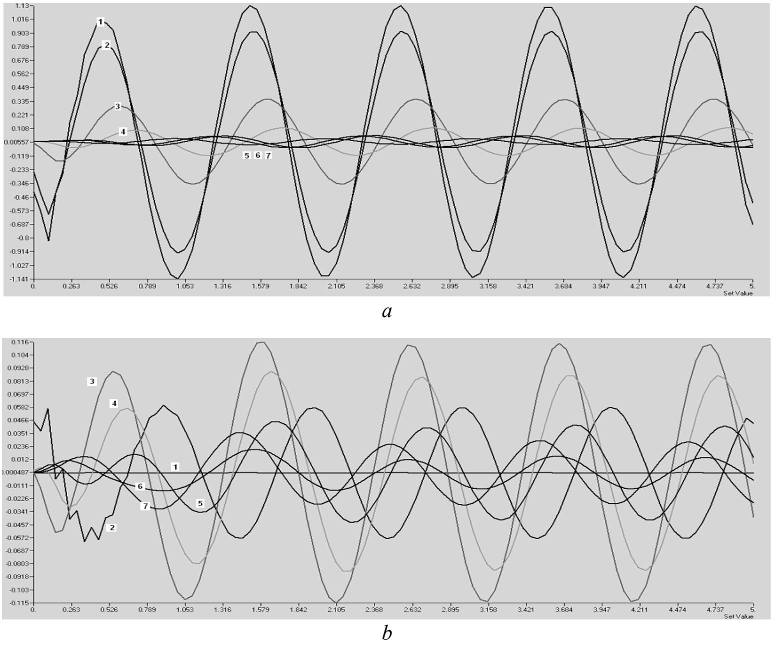
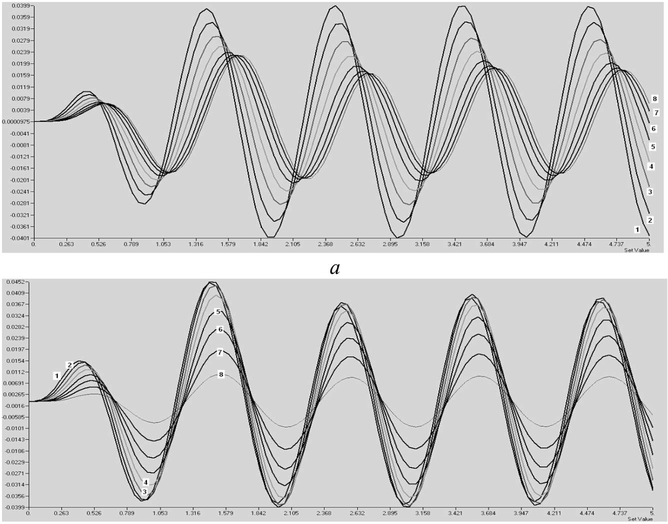


Fig. 7. Acceleration of the surface layer of soil
(1 – 0 *m*, 2 – 5 *m*, 3 – 10 *m*, 4 – 20 *m*, 5 – 30 *m*, 6 – 40 *m*, 7 – 50 *m*): a) vertical; b)horizontal

Maximum vertical acceleration of the surface layer of soil that is 1,14 m/sec^2, observed during a ballast prism in load location. The maximum horizontal acceleration of 0.116 m/sec^2 is observed at a distance of 10m from the place of loading. It can be seen that the vertical ground acceleration decreases with increasing distance to the location of the load. The horizontal ground acceleration ambiguously affected by this distance, so the acceleration of the ground at a distance of 40 *m* is 0,0256 m/sec^2, at 50 *m* – 0,0351 m/sec^2.

Consider the dynamic behavior of the surface layer of soil at a distance [60 – 100] *m* from the action of vertical load (fig. 8).

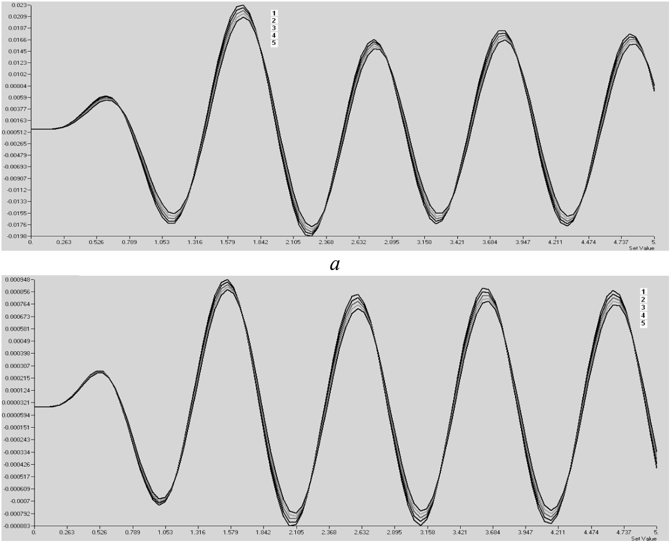
It is seen that with increasing distance vertical and horizontal acceleration of the surface layer of soil are decreases. The value of the vertical acceleration of the soil are in the range [0,045 – 0,023] m/sec^2, horizontal – [0,045 – 0,011] m/sec^2. The influence of rolling stock on the acceleration of soil layer depth [0 – 4]m at a distance of 95m from the place of loading are presented at the fig. 9.



a

b

Fig. 8. Acceleration of the surface layer of soil
(1 – 60 *m*, 2 – 65 *m*, 3 – 70 *m*, 4 – 75 *m*, 5 – 80 *m*, 6 – 85 *m*, 7 – 90 *m*, 8 – 95 *m*):
a) vertical; b)horizontal



a

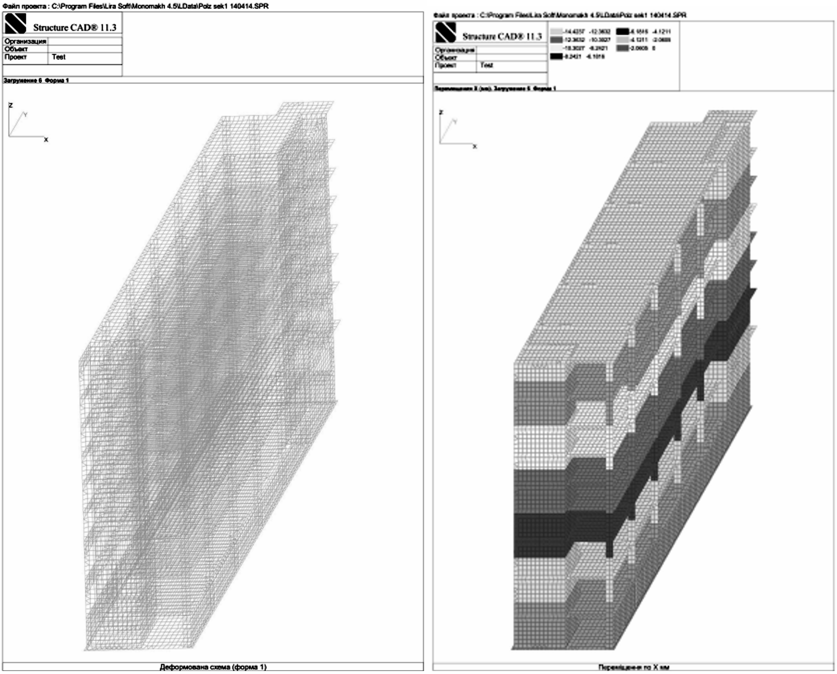
b

Fig. 9. Acceleration in depth soil layer at a distance 95 m
(1 – 0m, 2 – 1m, 3 – 2m, 4 – 3m, 5 – 4m) a) vertical; b)horizontal

It can be seen that the vertical and horizontal acceleration decreases with increasing depth of soil, but not much. The maximum vertical acceleration gain values from 0,023 m/sec^2 to 0,021 m/sec^2; horizontal – from 0,001 m/sec^2 to 0,0008 m/sec^2.

The resulting acceleration is the kinematic disturbance of soil on the basement level rise building. The acceleration in the form of vectors are applied to the respective nodes FEM building.

Calculation of basic bearing elements of the frame is made to verify the adopted constructive solutions and the size of the main load-bearing structural elements: piers, stiffness nuclear, elevator shafts, floor slabs and coatings. Calculations were performed designs according to the requirements of basic operating standards of design. The maximum horizontal displacement of the frame should be within 1/500 height of the building.



a *b*

Fig. 10. Results of the calculation framework: a) deformed scheme; b) horizontal displacements

The maximum horizontal displacement of the top of the frame is 14,42 *mm* (fig. 10, *b*), f/H= 14,42 / 27100 = 1 / 1000 < 1 / 500.

Consequently, the condition of the building horizontal deformation effects provided.

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Лук'янченко О.О., Костіна О.В., Геращенко О.В.

ВПЛИВ НАВАНТАЖЕННЯ ВІД РУХОМОГО СКЛАДУ НА ДИНАМІЧНУ ПОВЕДІНКУ БАГАТОПОВЕРХОВОЇ БУДІВЛІ

Виконане дослідження впливу навантажень від рухомого складу на багатоповерхову будівлю, що будується в зоні залізничних шляхів. Створені розрахункові МСЕ моделі баластової призми та будівлі у взаємодії з грунтом основи. Отримані прискорення грунту на рівні залягання фундаменту та оцінений їх вплив на динамичну поведінку будівлі.

Ключові слова: скінченноелементна модель, динаміка, рухомий склад, вібрації, прискорення грунту.

Лукьянченко О.А., Костина Е.В., Геращенко О.В.

ВЛИЯНИЕ НАГРУЗКИ ОТ ПОДВИЖНОГО СОСТАВА НА ДИНАМИЧЕСКОЕ ПОВЕДЕНИЕ МНОГОЭТАЖНОГО ЗДАНИЯ

Проведено исследование влияния нагрузок от подвижного состава на многоэтажное здание, строящееся в зоне железнодорожных путей. Построены расчетные МКЭ модели балластной призмы и здания во взаимодействии с грунтом основания. Получены ускорения грунта на уровне глубины заложения фундамента и оценено их влияние на динамическое поведение здания.

Ключевые слова: конечноэлементная модель, динамика, подвижной состав, многоэтажное здание, вибрации, ускорения грунта.