UDC 624.9 DOI: 10.31650/2786-6696-2024-10-17-26

THE IMPACT OF CHANGING THE TYPE OF CROSS-SECTION OF COLUMNS OF FRAME BUILDINGS

Volkova V., Dr. Sci. (Tech), Professor,
Dnipro State Agrarian and Economic University,
National University "Zaporizhzhia Polytechnic"
Ukrainian State University of Science and Technologies Educational and Scientific Institute
"Prydniprovska State Academy of Civil Engineering & Architecture"
drvev09@gmail.com, ORCID: 0000-0002-1883-1385
25 Serhiy Yefremov Street, Dnipro, 49000, Ukraine
Kovrova V., graduate student,
Ukrainian State University of Science and Technologies Educational and Scientific Institute
"Prydniprovska State Academy of Civil Engineering & Architecture"
kovrovaviktoriia@gmail.com, ORCID: 0009-0001-7733-7395
24A Architect Oleh Petrova Street, Dnipro, 49000, Ukraine

Abstract. Nowadays, the construction of multi-storey buildings is becoming increasingly important, leading to an increasing building density and the development of transport infrastructure. Recently, the volume of construction in areas exposed to vibrations of various nature has been steadily increasing. Constant impact of vibrations caused by external factors, such as traffic flows or industrial plants, on buildings can cause significant displacements of structural elements and increase noise levels, which is an additional negative effect on the safe operation of the building. Thus, the problem of controlling the impact of these vibrations on the reliability and durability of a building is becoming increasingly important.

Reducing the impact of frequencies on the structural characteristics of structures and on the normal functioning of the human body is implemented by vibration isolation of buildings and structural monitoring systems. However, the effect of changing the cross-sections of structural elements has not been fully investigated.

The aim of this work is to find rational cross-sectional shapes of columns in terms of material consumption and suitability for normal exploitation of multi-storey reinforced concrete frame buildings.

To analyse the effect of changing the cross-section of the columns, 3 variants of the column cross-section were developed, in which the shapes and geometric dimensions were changed. The geometric characteristics of the cross-sections were calculated using the Arbat software, and the modal analysis was performed using the SCAD software package.

As a result of the calculation, the interaction curves were obtained, which limit the area of the section's bearing capacity under the action of forces that can be applied to the section under analysis. In particular, the natural frequencies and shapes of vibrations were obtained, and the cross-sections of the columns were estimated by their area and moments of inertia. The changes in the type of column cross-section did not significantly affect the level of vibration frequencies of the building. However, it did change the material consumption and weight of the building by 24%, meaning that the values of the loads from the columns' own weight transmitted to the foundation also decreased. Reducing the loads on foundations can significantly reduce the cost of their construction. It was also found that a change in the type of section can affect the changing of the direction of movement of the building's vibration forms.

The results of the study demonstrate the possibility of optimising structural solutions by changing the geometry of columns, which not only saves resources but also ensures reliable operation of buildings.

Keywords: multi-storey reinforced concrete buildings, finite element method, numerical modeling, modal analysis, natural frequencies, rational cross-sectional shapes, form of oscillation.

Introduction. In today's environment, the construction of multi-storey buildings is becoming increasingly relevant, leading to an increase in building density and the development of transport infrastructure. Recently, the volume of construction in areas exposed to various vibrations has been steadily increasing. The constant impact of vibrations on buildings can cause significant displacements of structural elements and increase noise levels, which is an additional negative effect on the safe functioning of the building. Thus, the problem of controlling the impact of these vibrations on the reliability and durability of the building is becoming increasingly relevant. For this purpose, there is a need to monitor the state of structures on prototype design models using modal analysis [1].

Analysis of recent research. Modern urbanisation trends and the growing demand for high-rise buildings dictate the need to optimise materials and structures to ensure cost-effectiveness and energy efficiency. At the same time, increasing traffic and industrialisation are creating additional dynamic loads on buildings, which requires a more detailed investigation of their impact on structural elements.

The problems of cross-sectional shape formation of load-bearing structures are one of the fundamental problems. Traditionally, in the process of rational cross-section selection, architectural, structural and technological requirements are taken into account simultaneously, which in most cases conflict with each other. Sometimes approaches to reducing the material intensity of structures are in conflict with the requirements of simplicity of manufacturing technology, installation and even operation [2, 3].

In the last twenty years the traditional requirements of stability, strength and rigidity of structures have been supplemented by the need to check the structure for progressive collapse. It is known that the dominant influence on the formation of progressive collapse scenarios is exerted by the dynamic characteristics of the structure, and this phenomenon has already been realized in American standards. In view of this, the set of structural requirements described above is becoming wider.

Estimation of the natural frequency spectrum of structures was originally used to prevent resonance phenomena during operation. The natural frequencies of structures can be estimated analytically using approximate formulas. However, modal analysis provides more detailed and reliable data on the dynamic behavior of structures.

Despite the variety of software systems that implement the finite element method, not all of them allow to model reinforced concrete structures and perform their examination for compliance with construction standards. Application of computational complexes requires not only knowledge of mechanical properties of materials and geometry of structures, but also understanding of joint operation of individual structures. The peculiarities of the transition from structural to computational schemes of buildings and structures, as well as the fundamentals of computational mechanics are outlined in [4, 5].

The interest in the modal characteristics of buildings is not limited to the prediction of resonance phenomena. Today, modal characteristics are also used to assess possible damage. This is demonstrated in the research of mid-rise buildings in the works of L. Gaile, L. Ratnika, and L. Pakrastins [1, 3]. These studies have demonstrated the high efficiency of modal analysis and the importance of optimising design solutions to improve the reliability and cost-effectiveness of construction. In particular measures of various kinds are being implemented to reduce the impact of frequencies on the structural characteristics of structures and on the normal functioning of the human body: vibration isolation of buildings and structural health monitoring systems [3]. However, the option of changing the cross-sections of structural elements has not been fully investigated.

It is known from the theory of structures [4] that the study of the effect of loads on structural elements is combined with the analysis of the rigid and inertial properties of the structure and is related to the problems of predicting dynamic behaviour.

Analysing the dynamic behaviour of multi-storey buildings can not only improve performance but also minimise the risk of damage in seismically active regions. Thus, optimisation of column cross-sections can be an important factor in reducing construction costs, especially in areas with restrictions on foundation loads.

The aim of this work is to find rational cross-sectional shapes of columns in terms of material consumption and suitability for normal exploitation of multi-storey reinforced concrete frame buildings.

Materials and methodology of the study. In this study, it is necessary to investigate changes in the mass and stiffness of structures, taking into account the forms of movement and changes in frequencies for different types of cross-sections, in accordance with the equation of dynamics [5]:

$$M\ddot{\vec{y}} + K\vec{y} = \vec{p}, \tag{1}$$

where $\vec{y} = (y_1, y_2)^T$ – is the vector of displacements for the period T; y_1, y_2 – coordinates of the mass position; $\vec{p}$ – is the vector of vertical force action on the mass m; M – is the mass matrix:

$$M = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} = \begin{pmatrix} m & 0 \\ 0 & m \end{pmatrix}. \tag{2}$$

K is the stiffness matrix:

$$K = \begin{pmatrix} k_{11} & k_{12} \\ k_{21} & k_{22} \end{pmatrix} = \begin{pmatrix} s_1 + s_2 \cos^2\alpha & -s_2 \sin\alpha\cos\alpha \\ -s_2 \sin\alpha\cos\alpha & +s_2 \sin^2\alpha \end{pmatrix}, \tag{3}$$

where s_1, s_2 – is the elongation stiffeners; α – is the angle between linearly elastic rods carrying a concentrated mass m.

The structural scheme of the building is frame. The rigidity of the system is ensured by rigid bracing between columns and beams, as well as two stiffening cores [6]. The building foundation is slab and rigidly anchored. The building's structural elements are made of heavy concrete of strength class C25. The dimensions of the building in plan are 18×58 m, the height of the floor is 4.2 m. The building has 5 above-ground and 1 basement floors. The construction area is the city of Dnipro (Ukraine).

The cross-sectional dimensions of the columns are determined by architectural, structural, and technological requirements, so the considered cross-sections in all three variants do not exceed 500 mm along the outer contour.

The analysis was performed for 3 column cross-sectional shapes. The first of them has rectangular columns with dimensions of 500×500 mm. The second variant has I-section columns with dimensions of 500×500 mm with a shelf width of 180 mm, and the third has columns with a shelf width of 150 mm. Cross sections of the columns are shown in Figure 1.

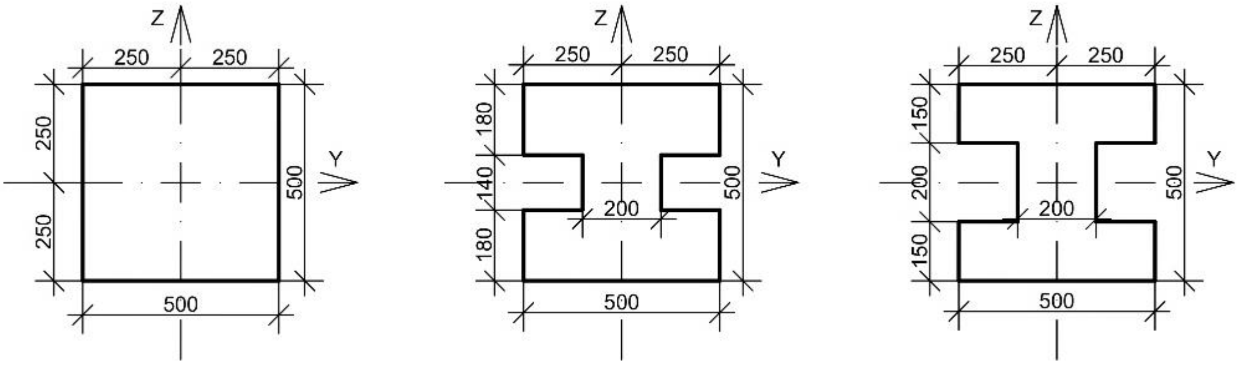

Fig. 1. Geometric dimensions of column sections

To calculate the geometric characteristics of the cross-sections for all three variants of the columns, the Arbat program, which is part of the SCAD computing software package, was used [6]. The calculation results are presented in Table 1.

According to the results obtained, it can be concluded that the cross-sectional area from the first to the third variant decreases by 24%, which characterizes a corresponding decrease in material consumption and weight of structures. The values of the moments of inertia also decrease from the first to the third case. For the moment of inertia relative to the central axis Y1 parallel to the Y axis (Iy), this reduction reaches about 4%, for the moment of inertia relative to the central axis Z1 parallel to the Z axis (Iz) – more than 37%, for the moment of inertia in free torsion (It) – more than 80%.

As a result of the calculation, the graphs of interaction curves were obtained using the Arbat program. These curves limit the area of bearing capacity of a section under the action of forces that can be applied to the cross-section being analyzed. These graphs for all types of sections are shown in Figure 2.

Table 1 – Characteristics of column sections

	Rectangular columns 500×500	I-section columns (shelf height 180)	I-section columns (shelf height 150)
Cross-sectional area (A), [cm^2]	2500	2080	1900
Moment of inertia relative to the central axis Y1 parallel to the axis Y (I_y), [cm^4]	520833	513973	500833
Moment of inertia relative to the central axis Z1 parallel to the axis Z (I_z), [cm^4]	520833	384333	325833
Moment of inertia in free torsion (I_t), [cm^4]	881250	231733	165833

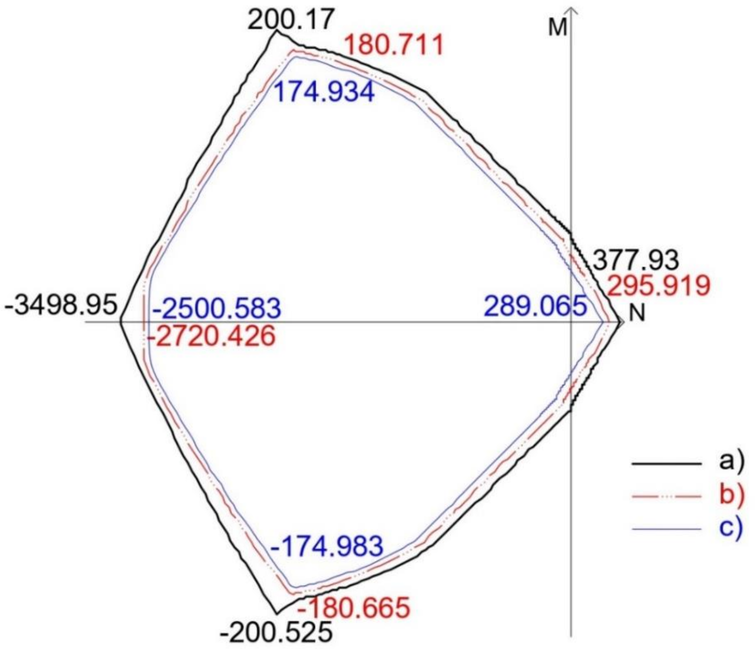

Fig. 2. Interaction curves:
a – 500×500 mm rectangular columns; b – I-section columns (180 mm shelf height); c – I-section columns (150 mm shelf height)

The design schemes were created using the SCAD software package, which implements the finite element method [7]. This method is basic in the analysis of structures in structural mechanics. Performing model discretization, which involves the distribution of structures into finite elements, is a very important and responsible process. This is due to the need to ensure the greatest relevance between the model and the structure [8]. The further reliability of the calculation depends on this. Thus, to ensure the accuracy of the calculation, elements of different shapes and sizes are used depending on the purpose of the task.

In the design scheme of the building, the columns are modeled using bar elements, and the floor slabs are modeled using plate elements. Bar elements are the simplest in the calculation of bar structures by the finite element method and can consist of two or more nodes. To create a discrete model of a two-dimensional area, two-dimensional finite elements are used, namely triangles and quadrilaterals, which can have a different number of nodes [9]. To ensure the most optimal discretization of the model, rectangular and triangular elements are used for two-dimensional structural elements. The use of the latter is due to the need to correctly ensure working conditions in the areas where columns adjoin floors.

According to the program definition, slabs are discretized as quadrilateral or triangular finite element shells, which were calculated using the Kirchhoff-Love plate theory.

The Kirchhoff-Love plate theory, or classical plate theory, was developed by Love [10], based on the assumptions proposed by Kirchhoff [11]. This theory is widely used in engineering science and practice to analyze the behavior of thin plates in the presence of lateral loading or bending moments along the plate boundary.

This theory operates on several key assumptions [12]. Firstly, it assumes that throughout the deformation process, the median surface of the plate remains neutral, meaning that the deformation in the median plane is neglected. Secondly, it postulates that the points on the plane perpendicular to the center surface remain on the plane perpendicular to the center surface after deformation. Thirdly, it asserts that the normal stress component in the thickness direction (σ_{zz}) is negligible compared to the in-plane normal stresses (σ_{xx} and σ_{yy}).

For small deflections of the plate, linearization is applied, and the curvature κ of any given plane parallel to the midplane is expressed by the deflection *w*. The following relations can be obtained using the angle of inclination of the plate *βi* at a point in the *i-th* direction and the in-plane displacements u_x and u_y [13].

$$\begin{array}{ll}
\beta_x := w_{,x} & \beta_y := w_{,y} \\
u_x := -\sin(\beta_x)\, z \approx -\beta_x z & u_y := -\sin(\beta_y)\, z \approx -\beta_y z \\
\kappa_x := -\beta_{x,x} = -w_{,xx} & \\
\kappa_y := -\beta_{y,y} = -w_{,yy} & \kappa_{xy} := -\beta_{x,y} = -w_{,xy} = -\beta_{y,x} = \kappa_{xy}
\end{array} \tag{4}$$

The deformations in the x and y directions due to pure bending of a thin plate at a distance z from the neutral midplane can be expressed as follows [12]:

$$\epsilon_{xx} = u_{x,x} = z\kappa_x, \qquad \epsilon_{yy} = u_{y,y} = z\kappa_y. \tag{5}$$

The non-zero components of the shear strain are of the form:

$$\Upsilon_{xy} = \Upsilon_{yx} := u_{x,y} + u_{y,x} = \beta_{x,y} + \beta_{y,x} = -2zw_{,xy} = 2z\kappa_{xy}. \tag{6}$$

Deformations in the Kirchhoff-Love theory of plates are linear functions of the distance from the midplane of the surface z and the second derivatives of the midplane deflection, which are equal to the corresponding curvatures at any given point.

The normal stress components are integrated over the thickness of the plate, resulting in expressions for the bending moments mx and my and the torsional moment m_{xy} [13]:

$$m_x := \int_{-t/2}^{t/2} \sigma_{xx} z dz, \qquad m_y := \int_{-t/2}^{t/2} \sigma_{yy} z dz, \qquad m_{xy} = m_{yx} := \int_{-t/2}^{t/2} \tau_{xy} z dz. \tag{7}$$

Similarly to the normal stress components, the shear stress components are integrated over the thickness of the plate, resulting in shear forces [13]:

$$q_x := \int_{-t/2}^{t/2} \tau_{xz} z dz, \qquad q_y := \int_{-t/2}^{t/2} \tau_{yz} z dz. \tag{8}$$

Using the above equations 7 and 8, the linearized local balance of linear and angular moments, taking into account the surface load per unit area *p(x, y)*, is as follows [13]:

$$q_{x,x} + q_{y,y} = -p \tag{9}$$

$$m_{xy,x} + m_{y,y} = -q_y \tag{10}$$

$$m_{x,x} + m_{yx,y} = -q_x. \tag{11}$$

Substituting q_x and q_y into 9 and using $m_{xy} = m_{yx}$ from 7, we obtain the local equilibrium in terms of bending and torsional moments per unit length of the plate [13]:

$$m_{x,xx} + 2m_{xy,xy} + m_{y,yy} = -p\,. \tag{12}$$

The generalized linear-elastic Hooke's law for the analysis of plane stresses, neglecting the normal stress components acting transversely to the median surface with Young's modulus E and Poisson's ratio ν, is as follows:

$$\epsilon_{xx} := \frac{1}{E}\left(\sigma_{xx} - \nu\sigma_{yy}\right), \qquad \epsilon_{yy} := \frac{1}{E}\left(\sigma_{yy} - \nu\sigma_{xx}\right), \qquad \Upsilon_{xy} = \frac{2}{E}\left(1+\nu\right)\tau_{xy}\,. \tag{13}$$

Using equations 4, 5, and 7, the defining relationship is expressed in terms of moments per unit length and plate bending stiffness K:

$$m_x = -K\left(w_{,xx} + \nu w_{,yy}\right)$$

$$m_y = -K\left(w_{,yy} + \nu w_{,xx}\right)$$

$$m_{xy} = -K\left(1-\nu\right)w_{,xy} \text{ with } K = \frac{Et^3}{12\left(1-\nu^2\right)}\,. \tag{14}$$

Substitution of these expressions into the local equilibrium 12 leads to the defining linear partial differential equation of the Kirchoff-Love plate bending:

$$w_{,xxxx} + 2w_{,xxyy} + w_{,yyyy} = \frac{p}{K} \text{ or } \Delta^2 w = \frac{p}{K}\,. \tag{15}$$

In a large number of software packages that use the finite element method, the process of element division is automated [14]. The type of finite elements of the building is a quadrangle, and the number of design elements and nodes is 50305 and 40231, respectively. To check the convergence of the results, different sizes of finite elements were used. As a result, the calculation results turned out to be close in value. The design scheme is shown in Figure 3.

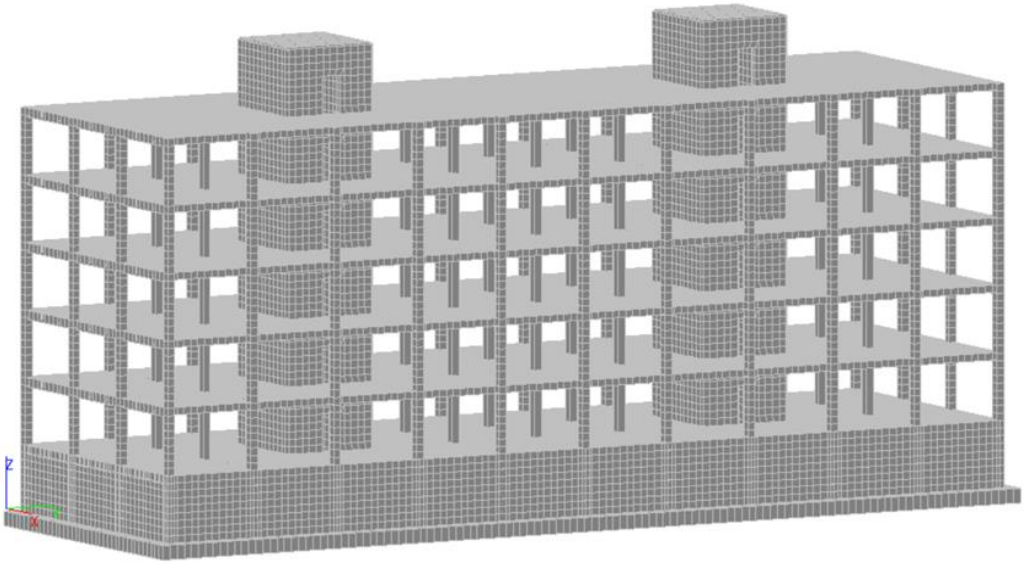

Fig. 3. Structural scheme

The developed design schemes take into account the effects of constant, long-term and short-term loads. Thus, the strength of the building structures was calculated, stress and displacement fields were obtained, in particular, the modal analysis of natural frequencies was performed.

The modal analysis provides data on the dynamic behavior of the building, which consists in determining the main forms of oscillations and their corresponding natural frequencies [1]. The results of the modal analysis are necessary to optimize the building structure to increase its stability and reduce vibrations and stresses in materials [15].

The calculation of buildings was performed using the multifrontal method in the SCAD software package [5, 7]. This method is based on the Gaussian method. This method provides for the parallelism of the locations and exclusions of the already collected equations. The ordering of equations is carried out using heuristic approaches, which involves the creation of several fronts [5].

Research results. As a result of the modal analysis, natural frequencies and vibration forms were obtained. The graphic results of the calculation are shown in Figures 4-6.

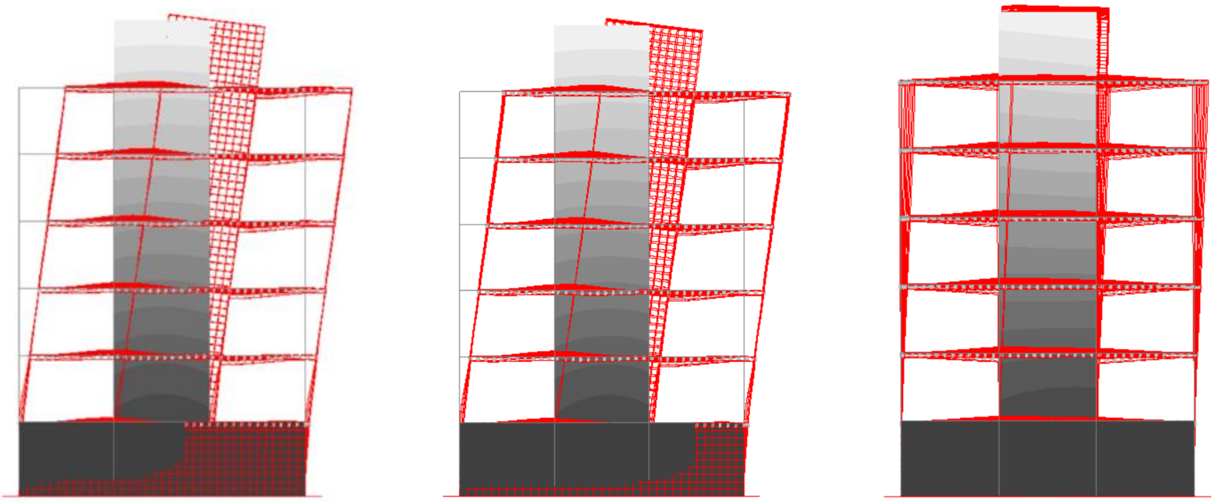

Fig. 4. The first form of oscillation:
a – 500×500 mm rectangular columns; b – I-section columns (180 mm shelf height); c – I-section columns (150 mm shelf height)

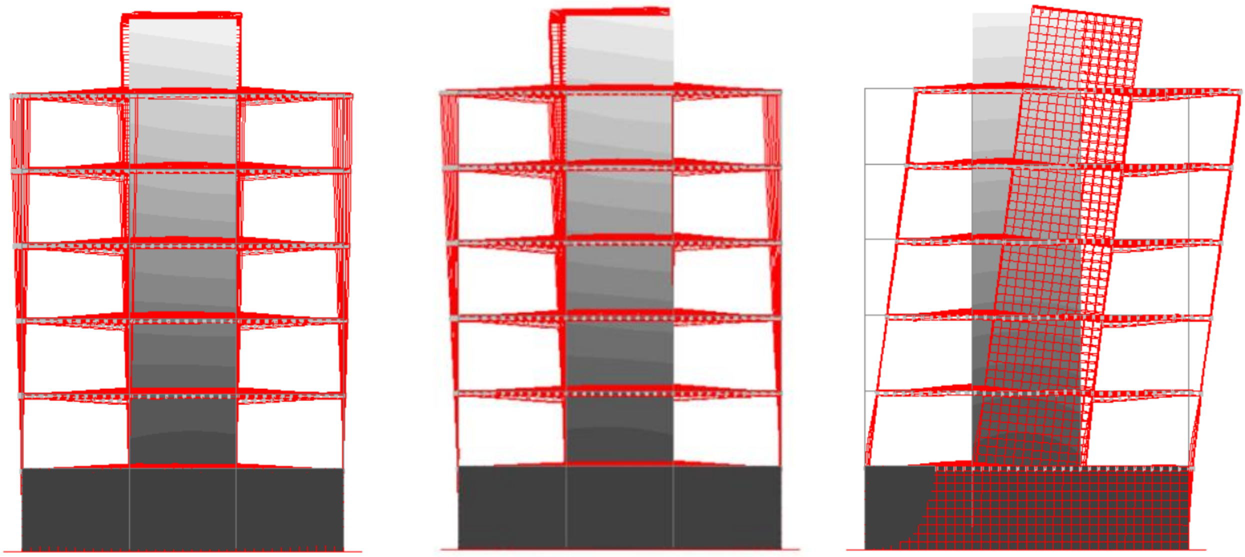

Fig. 5. The second form of oscillation:
a – 500×500 mm rectangular columns; b – I-section columns (180 mm shelf height); c – I-section columns (150 mm shelf height)

The number of forms was determined based on the percentage of the collected effective modal masses in accordance with the requirements of DBN B.1.1-12:2014 [16]. The first 10 forms of each variant of the design schemes are considered in more detail [7, 17]. The modal analysis was performed for all three cross-sectional variants.

According to the program's reports on eigenvalues and frequencies, it can be concluded that the change in cross-section had a minimal effect on these indicators. In terms of percentage, the difference between the I-section and the rectangular section did not reach more than 10%. However, as a result of changing the types of cross-sections, there is a change in the directions of movement of the modes. Thus, in the first form, in the calculations with rectangular and I-section columns with a shelf width of 180 mm, the movement occurs along the X-axis, and in the model where the columns are represented by an I-section with a shelf width of 150 mm - along the Y-axis, as shown in Figure 4. In the second form of natural oscillations, in the first two of these computational models, translational motion is carried out along the Y axis, and in the last scheme - along the X axis, as shown in Figure 5. In other forms of natural oscillations, the change in direction or type of motion is minimal, as shown in Figure 6.

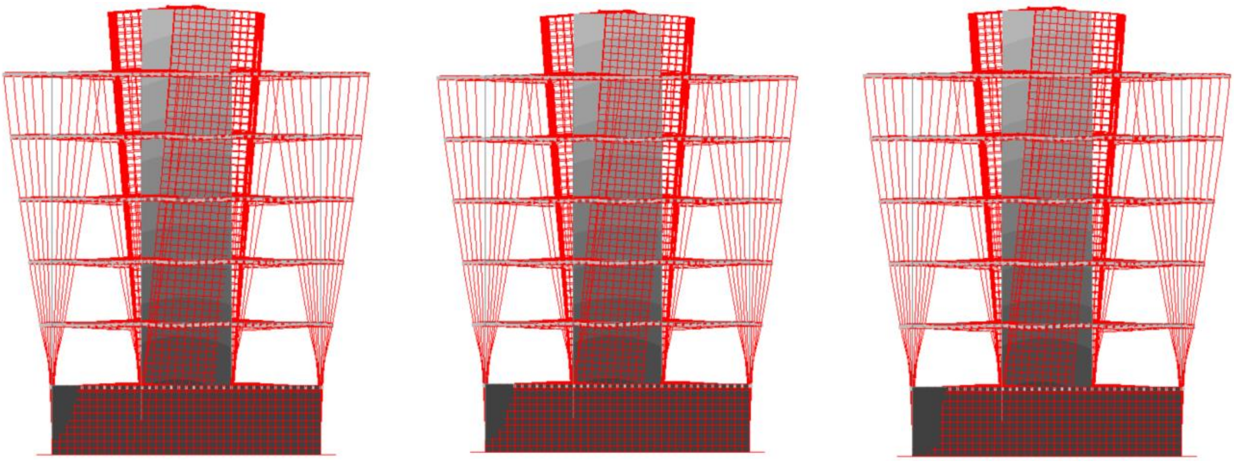

Fig. 6. The third form of oscillation:
a – 500×500 mm rectangular columns; b – I-section columns (180 mm shelf height);
c – I-section columns (150 mm shelf height)

According to the results obtained, it can be concluded that the change in the type of column cross-section did not significantly affect the level of the building's vibration frequencies. However, it did affect the change in material consumption and weight of the building by 24%, as well as the moments of inertia. In particular, it was found that changing the type of cross-section can affect the change in the direction of movement of the building's vibration forms.

Conclusion. As a result of the investigation, important data were obtained on the effect of changes in the geometry of the cross-section of columns on the dynamic behaviour of multi-storey reinforced concrete frame buildings.

Changing the type of column cross-section can significantly reduce the material consumption and weight of a building. The research showed that by switching from a rectangular cross-section to an I-shaped cross-section, the cross-sectional area of the columns is reduced by 24%. This reduces the weight of the structure, which in turn reduces the load on the foundation and helps to save money during the design and construction phases.

The modal analysis showed that changing the geometry of the column cross-section affects the direction of movement of the building's vibration forms, but does not have a significant impact on the values of the natural vibration frequencies. For all three cross-sectional variants considered, the frequency changes do not exceed 10%. This indicates that it is possible to optimise structures without significantly affecting their dynamic stability.

The analysis showed that the transition to I-shaped column sections significantly reduces the moments of inertia, especially the free torsion moment (I_t), which decreased by 80%. This change may affect the behaviour of structures under combined loads, which should be taken into account in further design.

The obtained results indicate the feasibility of using I-shaped column sections in the construction of multi-storey buildings, where material savings and reduced foundation loads are important. Reducing the dead weight of structures has a positive effect on the overall costs and duration of the construction of the facility.

According to the obtained results it is advisable to extend the study to a larger number of section types that correspond to modern materials and technologies.

References

[1] L. Gaile, L. Ratnika, L. Pakrastins, "RC Medium-Rise Building Damage Sensitivity with SSI Effect", *Material*s, vol. 15, no. 5, pp. 1653, 2022. URL: https://doi.org/10.3390/ma15051653.

[2] L. Skoruk, "Features of the calculation of reinforced concrete elements under the action of transverse force according to different standards", Building constructions. Theory Pract., vol. 13, pp. 139–148, 2023. URL: https://doi.org/10.32347/2522-4182.13.2023.139-148.

[3] L. Gaile, I. Radins, "Evaluation of vibration-based global structural health monitoring method for medium-rise buildings", *Environment. Technologies. Resources. Proceedings of the International Scientific and Practical Conference*, vol. 1, pp. 55-61, 2021. URL: https://doi.org/10.17770/etr2021vol1.6598

[4] V.A. Bazhenov, Yu.V. Vorona, A.V. Perelmuter, *Budivelna mekhanika i teoriia sporud. Narysy z istorii*, Kyiv: Caravela, 2016.

[5] V.A. Bazhenov, A.V. Perelmuter, O.V. Shyshov, *Budivelna mekhanika. Kompiuterni tekhnolohii i modeliuvannia*, Kyiv: Caravela, 2009.

[6] V. Kovrova, V. Volkova, L. Pakrastins, "Modal Analysis of a Multi-storey Frame Building with Consideration of the Soil Base", *Modern Building Materials, Structures and Techniques*, vol. 392, pp. 668-673, 2024. URL: https://doi.org/10.1007/978-3-031-44603-0_69.

[7] V.S. Karpylovskyi, E.Z. Kryksunov, A.A. Maliarenko, A.V. Perelmuter, M.A. Perelmuter, S. Iu. Fyalko, *SCAD Office.Versyia 23.Vichyslytelnii kompleks SCAD++*, Kyiv: Yzdatelstvo «SCAD SOFT», 2024.

[8] S.I. Homeniuk, V.Iu. Kozub, "Parallelna realizatsiia metodu skinchennnykh elementiv dlia zadachi termopruzhnosti", *Bulletin of the Volodymyr Dahl East Ukrainian National University*, vol. 5, no. 275, pp. 5-9, 2022. URL: https://doi.org/10.33216/1998-7927-2019-256-8-5-9.

[9] Metod kintsevih elementiv. [Online]. URL: https://stud.com.ua/54925/tovaroznavstvo/metod_kintsevih_elementiv/ Accessed on: May 3, 2024

[10] A.E.H. Love, "The small free vibrations and deformation of a thin elastic shell", *Philosophical Transactions of the Royal Society of London*, vol. 179, pp. 491–546, 1888. URL: https://doi.org/10.1098/rsta.1888.0016.

[11] A. Cazzani, L. Rosati, P. Ruge, "The contribution of Gustav R. Kirchhoff to the dynamics of tapered beams", *Journal of Applied Mathematics and Mechanics / Zeitschrift für Angewandte Mathematik und Mechanik*, vol. 97, no. 10, pp. 1174-1203, 2017. URL: https://doi.org/10.1002/zamm.201600250

[12] S. Timoshenko, S. Woinowsky-Krieger, *Theory of plates and shells*, New York, McGraw-Hill, 1959.

[13] G.A. Holzapfel, *Nonlinear Solid Mechanics: A Continuum Approach for Engineering*, John Wiley & Sons, 2000.

[14] W.K. Liu, S. Li, H. S. Park, "Eighty Years of the Finite Element Method: Birth, Evolution, and Future", *Archives of Computational Methods in Engineering*, vol. 29, pp. 4431–4453, 2022. URL: https://doi.org/10.1007/s11831-022-09740-9.

[15] V. Kovrova, V. Volkova, "Analysis of the influence of different soil types on the natural frequencies of multi-storey reinforced concrete buildings", *Strength of Materials and Theory of Structures*, vol. 111, pp. 172-177, 2023. URL: https://doi.org/10.32347/2410-2547.2023.111.172-177.

[16] DBN V.1.1-12:2014, Budivnytstvo v seismichnykh raionakh Ukrainy, Minregion Ukrainy, Kyiv, 2014.

[17] A. Gee, S.M. Hashemi, "Undamped Free Vibration Analysis of Functionally Graded Beams: A Dynamic Finite Element Approach", *Applied Mechanics*, vol. 3, no. 4, pp. 1223-1239, 2022.URL: https://doi.org/10.3390/applmech3040070.

ВПЛИВ ЗМІНИ ТИПУ ПЕРЕРІЗУ КОЛОН КАРКАСНИХ БУДІВЕЛЬ

Волкова В.Є., д.т.н., професор,
Дніпровський державний аграрно-економічний університет,
Національний університет «Запорізька політехніка»
Український державний університет науки і технологій Навчально-науковий інститут «Придніпровська державна академія будівництва та архітектури»
drvev09@gmail.com, ORCID: 0000-0002-1883-1385
вул. Сергія Єфремова, 25, Дніпро, 49000, Україна
Коврова В.О., аспірантка,
Український державний університет науки і технологій Навчально-науковий інститут «Придніпровська державна академія будівництва та архітектури»
kovrovaviktoriia@gmail.com, ORCID: 0009-0001-7733-7395
вул. Архітектора Олега Петрова, 24А, Дніпро, 49000, Україна

Анотація. У сучасних умовах будівництво багатоповерхових будинків стає все більш актуальним, що призводить до збільшення щільності забудови та розвитку транспортної інфраструктури. Останнім часом неухильно зростають обсяги будівництва в зонах, що піддаються вібраціям різного характеру. Постійний вплив вібрацій, спричинених зовнішніми чинниками, такими як транспортні потоки або промислові установки, на будівлі може викликати значні зміщення конструктивних елементів і підвищувати рівень шуму, що є додатковим негативним впливом на безпечне функціонування будівлі. Таким чином, проблема контролю впливу цих вібрацій на надійність і довговічність будівлі стає все більш актуальною.

Зменшення впливу частот на структурні характеристики конструкцій та на нормальне функціонування організму людини впроваджується за допомогою віброізоляції будівель та систем моніторингу стану конструкцій. Однак вплив зміни перерізів конструктивних елементів не досліджено повністю.

Метою даного дослідження є пошук раціональних конструктивних рішень з точки зору матеріаломісткості та експлуатаційної придатності будівлі, що знаходиться під впливом динамічних навантажень.

Для аналізу впливу зміни поперечного перерізу колон було розроблено 3 варіанти поперечного перерізу колон, у яких змінювалися форми та геометричні розміри. Геометричні характеристики перерізів розраховувалися за допомогою програми "Арбат", а модальний аналіз виконувався за допомогою програмного комплексу SCAD.

В результаті розрахунку були отримані графіки кривих взаємодії, обмежують область несучої здатності перерізу під дією зусиль, які можуть бути прикладені до перерізу, що аналізується. Зокрема одержано власні частоти і форми коливань, а також оцінені поперечні перерізи колон за їх площею і моментами інерції. Зміна типу перерізу колон не суттєво вплинула на рівень частот коливань будівлі. Однак вона змінила матеріаломісткість і вагу будівлі на 24%, тобто значення навантажень від власної ваги колон, що передаються на фундамент також знизилися. Зниження навантажень на фундаменти дозволяє суттєво скоротити витрати на їх улаштування. Також було виявлено, що зміна типу перерізу може впливати на зміну напрямку руху форм коливань будівлі.

Результати дослідження демонструють можливість оптимізації конструктивних рішень через зміну геометрії колон, що дозволяє не лише економити ресурси, але й забезпечувати надійну експлуатацію будівель.

Ключові слова: багатоповерхові залізобетонні будівлі, метод скінченних елементів, чисельне моделювання, модальний аналіз, власні частоти, раціональні форми поперечних перерізів, форма коливань.

Стаття надійшла до редакції 5.12.2024