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PROBLEMS OF SOFTWARE COMPLEXES APPLICATION IN CONSTRUCTION STRUCTURES CALCULATIONS

Abstract. The article considers the stages of building structures calculations during the pre-computer period and after the introduction of computers into the engineering process. The article describes the functions and capabilities of modern calculated software systems used to improve the automation rate and the quality of designing and erecting buildings. The possible problems of calculated software complexes are clarified, and attention is focused on the lack of the information base about methods of forming frameworks calculated schemes in software complexes. Examples confirm the analyzing necessity calculation results in software packages. Conclusions in further research about calculated software systems using are formulated.

Keywords: software complex, calculated schemes, calculation, calculation methods, building structures, design, automation, framework.

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ПРОБЛЕМЫ ПРИМЕНЕНИЯ ПРОГРАММНЫХ КОМПЛЕКСОВ В РАСЧЕТАХ СТРОИТЕЛЬНЫХ КОНСТРУКЦИЙ

Аннотация. В статье рассматривают этапы выполнения расчетов строительных конструкций в докомпьютерный период и после внедрения электронно-вычислительных машин в процесс проектирования зданий. Описываются функции и возможности современных расчетных программных комплексов, предусмотренные для повышения скорости, уровня автоматизации и качества выполнения задач по проектированию и конструированию объектов строительства. Уточняются возможные проблемы, возникающие при использовании расчетных программных комплексов, а также акцентируется внимание на недостатке нормативной базы относительно методов построения расчетных схем каркасов зданий в программных комплексах. Приводятся примеры, подтверждающие необходимость проведения анализа результатов расчета каркасов зданий в программных комплексах. Формулируются выводы относительно дальнейшего проведения исследований в области расчета строительных конструкций с применением программных комплексов.

Ключевые слова: программный комплекс, расчетная схема, расчет, методы расчета, строительные конструкции, проектирование, автоматизация, каркас здания.

Introduction

It is not a secret for anyone that the 21st century is the century of scientific and technological progress, which has not left aside any of the branches of human life. The construction industry is also no exception. The introduction of innovative technologies occurs at all stages of the construction of a building, from the creation of a preliminary design to the commissioning of an already constructed building.

Especially nowadays there is an active application and improvement of computer-aided design systems. Design automation allows you to improve the quality of work, while reducing design time and increasing the productivity of engineering and technical workers. The use of modern computational software systems should presumably allow the most rational approach to the issue of the consumption of building materials and thereby reduce their costs. Computer-aided design systems based on the latest achievements of fundamental sciences make it possible to improve its methodology, to stimulate the development of the mathematical theory of designing complex systems and objects.

In this regard, a large number of studies are being carried out to improve software systems, which practically without restrictions allow calculating buildings and structures of any degree of complexity - in statics and dynamics, in elastic and inelastic stages of work, taking into account the sequence and technology of building construction, including changes in the structural schemes and the emergence of new

loads during reconstruction.

Also, recently enough works have been published in which design schemes were drawn up for specific buildings with almost complete correspondence of the real geometric dimensions and physical and mechanical properties of the simulated object in order to assess its stress-strain state and predict its behavior.

It can be concluded that the use of computational software systems using the capabilities of automating the execution of calculations has become an integral part of the design process

construction objects.

At the same time, there are practically no works that would confirm the feasibility of replacing the classical methods of constructing design schemes in software systems with partially manual execution of structural calculations for the use of the most complicated and well-developed design scheme to increase the degree of automation of the calculation process.

Thus, the purpose of this work is to identify the need to analyze the results when performing calculations of building frames in software systems. To achieve this goal, the following tasks have been set:

- determine the nature of the development of the process of performing calculations of building structures;
- highlight the capabilities inherent in modern software systems;
- to identify the problems that designers may face when working in computational software systems.

The history of the development of performing calculations of building structures

Two periods can be distinguished in the development of performing calculations of building structures.

Initially, calculations were performed, as well as in solving simple tasks, are still performed using methods that can be performed manually, based on the rules formulated in structural mechanics and the strength of materials.

However, with the development, massive introduction and use of electronic computers (computers) in the construction field, the approach to performing calculations of building structures also began to change. This is the period of development of computer technology, which continues now.

Approaches to the calculation of building structures before the advent of computers

Until the 60s of the XIX century, which can be characterized as the pre-computer period, methods for the numerical calculation of building structures were developed, which assumed a number of simplifications for manual calculations. The main ones are as follows:

• when distributing forces in the structure, only the influence of bending moments is considered, and the influence of longitudinal and transverse forces is not considered;

• when constructing design schemes, the work of nodes is clearly divided into rigid or hinged, without considering the possibility of partial pinching;

• in manual calculation methods, only the linear statement of material deformation is considered;

• separation of calculations for bar systems and plastic structures.

The main methods used to calculate indeterminate bar systems are the force method and the displacement method.

When calculating by the method of forces, the main required values are the efforts in the extra connections.

When calculating by the displacement method, the main required quantities are the displacements of the nodal points caused by the deformation of the system.

At the same time, it is possible to use two methods together in special cases, that is, a combined method, when part of the unknowns is represented by efforts, and the other part is represented by displacements.

Despite the fact that the above methods imply simplifications in the presence of a large number of elements in the design scheme and degrees of static uncertainty of the system, as a result, it may be necessary to solve a system of linear equations with high-order dimensions (10), which ultimately is a rather voluminous and complex problem.

Approach to the calculation of building structures with the advent of computers

With the development of computer technology and the massive introduction of computers, the finite element method (FEM) has become one of the most popular, widespread and effective numerical calculation methods both in Russia and around the world.

The main idea of the FEM is that any continuous value in a certain area (for example, internal force in a foundation beam, displacement in a floor slab, etc.) can be replaced by a model that is created from a set of piecewise continuous functions defined in a finite number elements. Such functions can be linear, quadratic, cubic, etc. Piecewise continuous functions are constructed using the values of a continuous quantity at the connection points of the elements (at the nodes). Thus, in order to determine an unknown continuous value, you need to determine its values at the node.

With the development of this method, it became possible to solve pivotal and plastic problems using one technique. Moreover, it became possible to solve combined tasks that contain both bar elements (frames, columns, beams, girders) and plate elements (slabs that are built in the form of plates).

The development of FEM is closely related to the development of computer technology, due to which it became possible to speed up the process of solving complex numerical problems. As well as the development of technology, has led to the creation and improvement of computer software systems (PC) that implement FEM.

The most widely known and used software systems are PC LIRA, PC SCAD Office, PC MONOMAH, STARK ES, largely due to their availability, breadth of distribution, compliance with SP and GOST.

Possibilities that are assumed when using computational software systems

The development of the PC, like the improvement of computing technology, occurs gradually.

So, when the first computers appeared, the output of the results of solving systems of equations using a PC was possible only in matrix form. That is, all data were entered into the program in the form of matrices and the necessary values of efforts were also displayed in the form of matrices.

Over time, it became possible to solve problems in a flat construction with the display of a design scheme (for example, a frame made of rods or a plate displayed in the form of a plate divided into segments).

Later, it became realistic to divide the problems into solutions in a linear and non-linear formulation to achieve more accurate results (thin shells, reinforced concrete structures). And, the methods of selection of the required dimensions of sections of structures are implemented directly in the PC.

Currently, PCs have received such development that, when using them, designers can perform a number of tasks, which include:

1) Performing calculations based on the finite element method:

• static calculations with the determination of efforts both in linear and nonlinear formulation, considering the geometric and physical nonlinearity of the model;

• dynamic calculations, including the determination of the forms and frequencies of natural vibrations, the pulsation component of the wind and calculation of seismic loads;

• calculations at the stage of stage-by-stage installation of the building;

• calculation for progressive collapse;

2) Constructive calculations:

• determination of hazardous design combinations of forces in the sections of elements and hazardous reactions, including considering the possible variability of the design scheme;

• calculation and selection of reinforcement, as well as verification of elements of reinforced concrete structures by calculation of limit states;

• calculation of steel structure elements for strength, general and local stability, calculation of welded seams, selection of sections of rolling elements for stresses;

• calculation of typical joints of structures.

In addition to the ability to perform calculations, many PCs include additional useful functions that do not affect the calculations but can reduce the likelihood of errors in the process of understanding and drawing up design schemes.

So, for example, the LIRA-SAPR developers in one of the latest versions of the program implemented the function of redistributing the linear load to the nodal one, which makes it possible to simplify the process of applying loads in the design scheme. This function is especially useful when designing a pitched roof with heights at several levels and the presence of dormer windows in it.

Another useful function of modern PCs can be called 3D modeling, not only of the entire building, but also the display of conjugation nodes of structures in space.

And also to reduce the time for the design and eliminate the repetition of construction operations in many PCs, the technology of joint use of independently developed graphic and computational software systems is laid due to the automatic transfer of drawings from one program to another with minimal data loss.

However, one should not ignore the fact that in order to use the capabilities and advantages of computational software systems described above, most often it becomes necessary to perform a detailed study of the computational scheme, and you should also clearly understand the algorithm of the PC in order to obtain correct results.

Disadvantages of using computational software systems at the present time

Undoubtedly, using a PC for performing calculations greatly simplifies and speeds up the design process. But we must never forget that the program is just a tool for deriving the calculation results, the criteria and parameters of which are set by the designer.

Experienced specialists understand often the results of calculations using a PC are not unambiguous.

Very often using the same PC, designers can get different results. This can be explained by the fact that modern PCs contain various means of transition from a real design to its mathematical model, and, at the same time, approaches to the implementation of this mathematical model can be formulated in different ways.

In this regard, the lack of clear generally accepted rules and recommendations for drawing up design schemes using a PC for buildings and structures, depending on their type, purpose, structures used, etc. leads to the fact that the designer formulates his own work algorithm, based on personal experience, which may differ from the approach of other designers, which leads to the ambiguity of the final results.

As an example, let us consider three variants of the calculation performed using the LIRA-SAPR software package for the floor slab of a multi-storey building.

In the first case, the slab is calculated as a structure in the entire building frame. In the second case, the slab was separated from the structure of the frame, built for the calculation of case 1, and for the third case, a separate design scheme of the floor slab was drawn up in the PC (see Fig. 1).

The principles of composing load cases for performing the calculation in the three cases also differ. In the case of a separate construction of the design model of the floor slab, all the acting loads were taken into account and specified by separate load cases (see Fig. 3), while in the case of the calculation for the first case (calculation of the slab as part of the building frame) and the second, the loads are given in general form, depending on the nature of their action (see Fig. 2). Also, for the calculation according to the first option, in connection with the construction of the entire frame in the software package, the pulsation components of the wind load were considered.

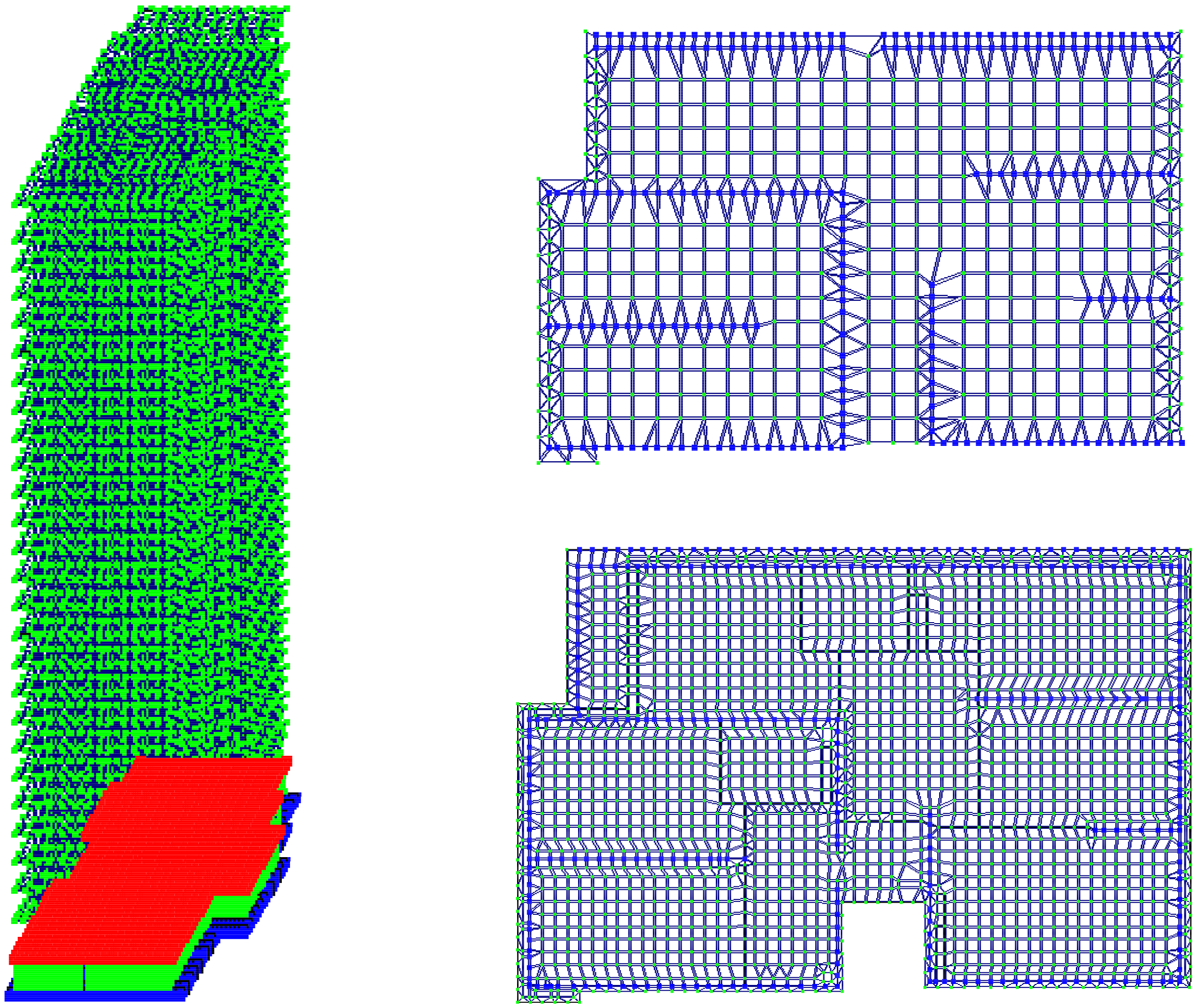
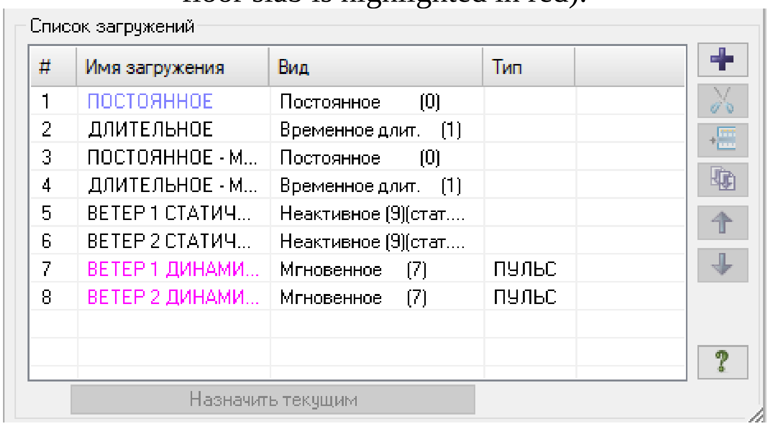


Figure 1. The design model of the building frame, the design model of the slab cut from the building frame, and the design model of the slab compiled separately (the location of the calculated floor slab is highlighted in red).



Список загружений

#	Имя загружения	Вид	Тип
1	ПОСТОЯННОЕ	Постоянное (0)	
2	ДЛИТЕЛЬНОЕ	Временное длит. (1)	
3	ПОСТОЯННОЕ - М...	Постоянное (0)	
4	ДЛИТЕЛЬНОЕ - М...	Временное длит. (1)	
5	ВЕТЕР 1 СТАТИЧ...	Неактивное (9)(стат....	
6	ВЕТЕР 2 СТАТИЧ...	Неактивное (9)(стат....	
7	ВЕТЕР 1 ДИНАМИ...	Мгновенное (7)	ПУЛЬС
8	ВЕТЕР 2 ДИНАМИ...	Мгновенное (7)	ПУЛЬС

Назначить текущим

Figure 2. List of load cases in the case of compiling a design model of the building frame (cases 1 and 2).

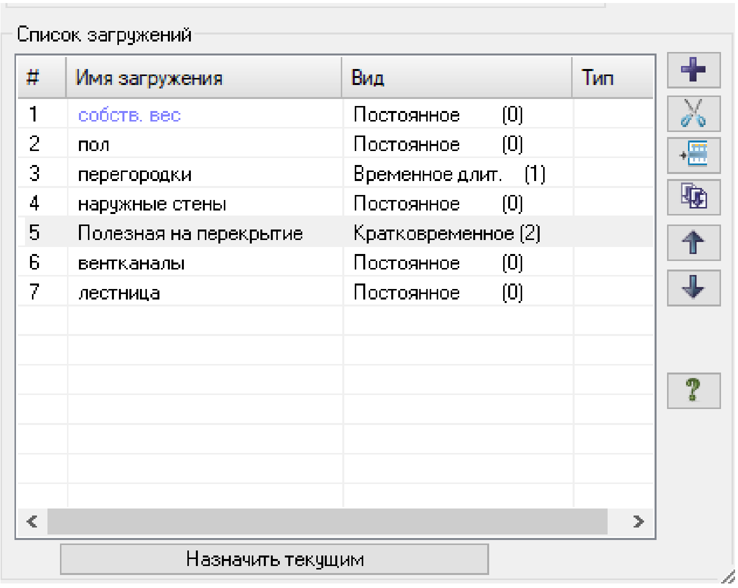


Figure 3. List of load cases in the case of drawing up a design model for an individual slab (case 3)

Comparing the obtained stress isofields after performing the calculations, it can be seen that their distribution has a similar character (see Fig. 4 - 9).

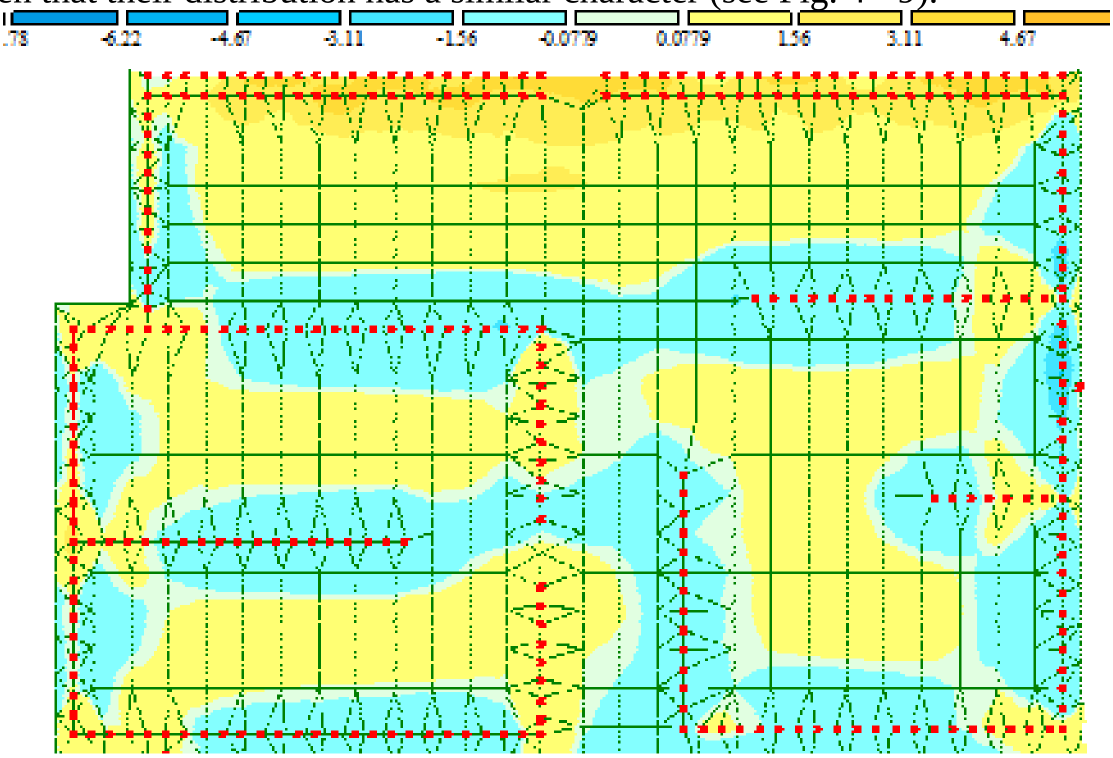


Figure 4. Isofields of stresses according to M_y in the case of calculating the floor slab when constructing the design model of the building frame (case 1).

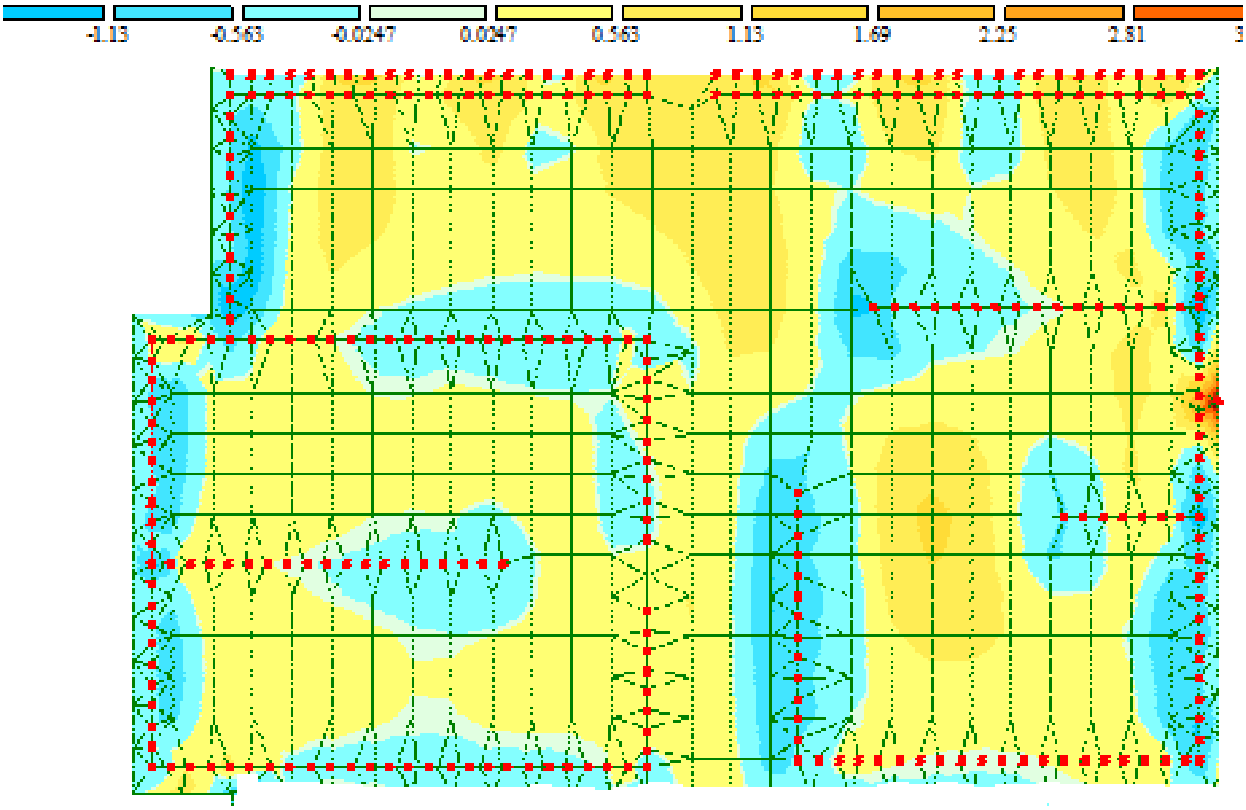


Figure 5. Isofields of stresses in M_x in the case of calculating a floor slab as part of a building frame (case 1)

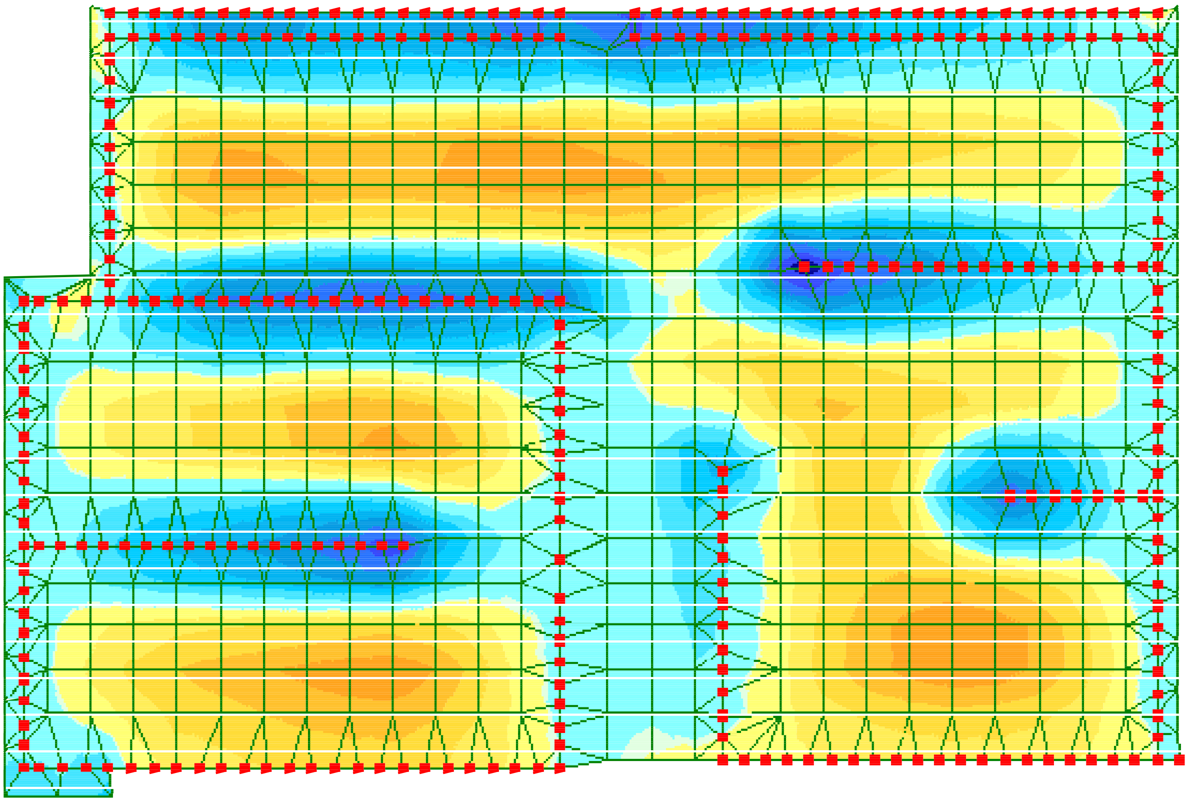


Figure 6. Isofields of stresses according to M_y in the case of cutting the floor slab from the building frame (case 2)

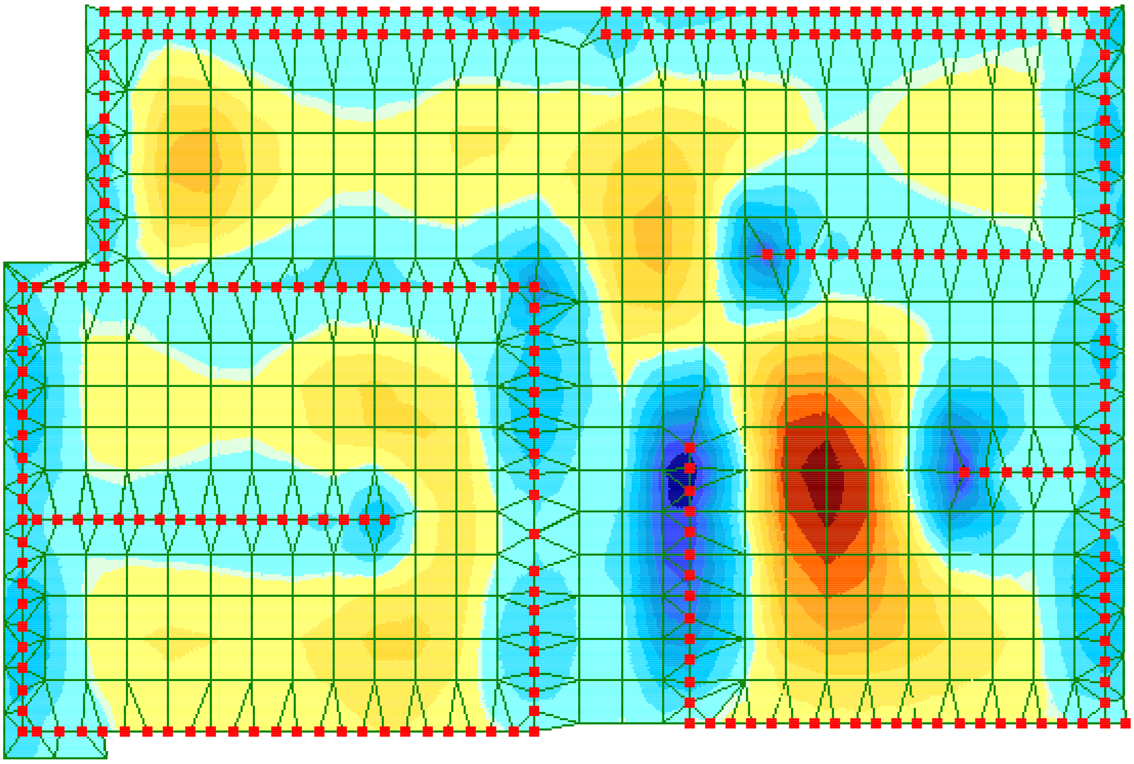


Figure 7. Isofields of stresses in M_x in the case of cutting a floor slab from the building frame (case 2)

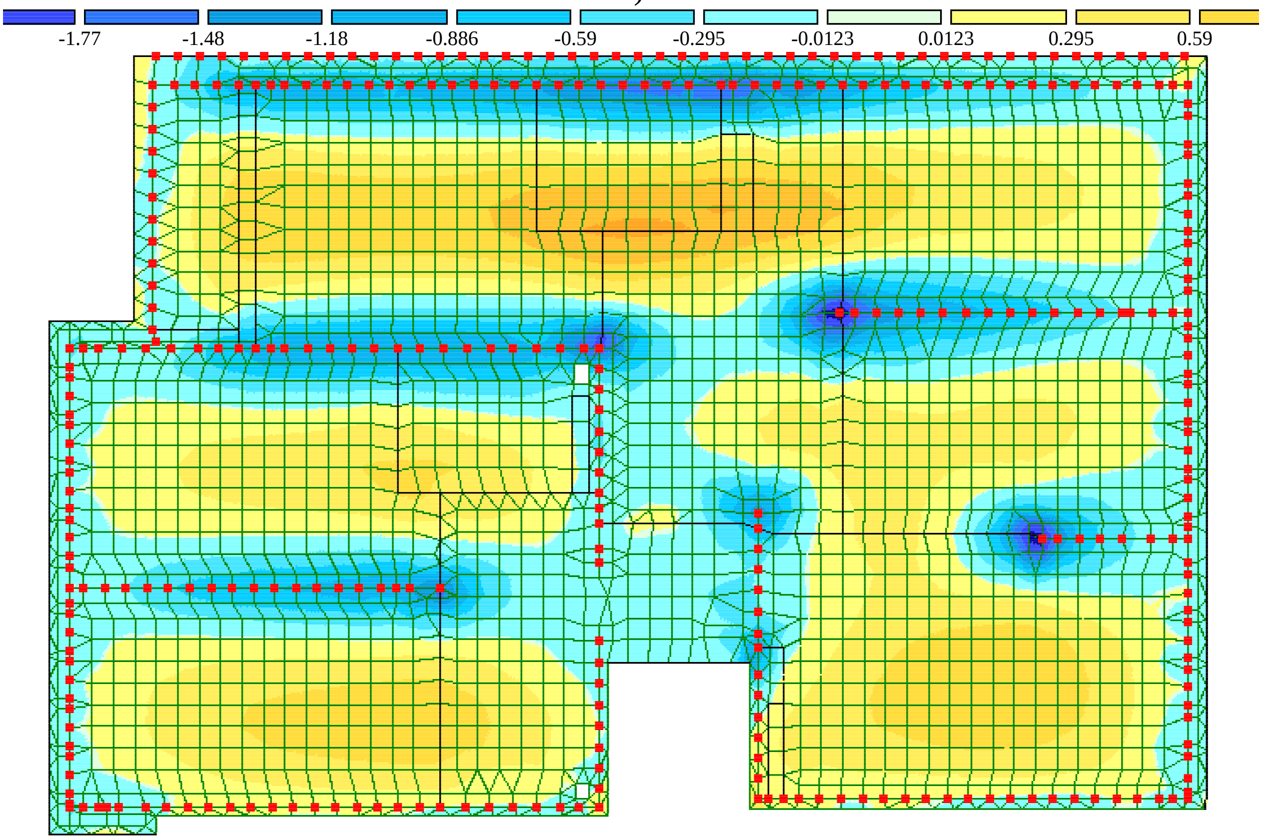


Figure 8. Isofields of stresses according to M_y in the case of a separate calculation of the floor slab (case 3)

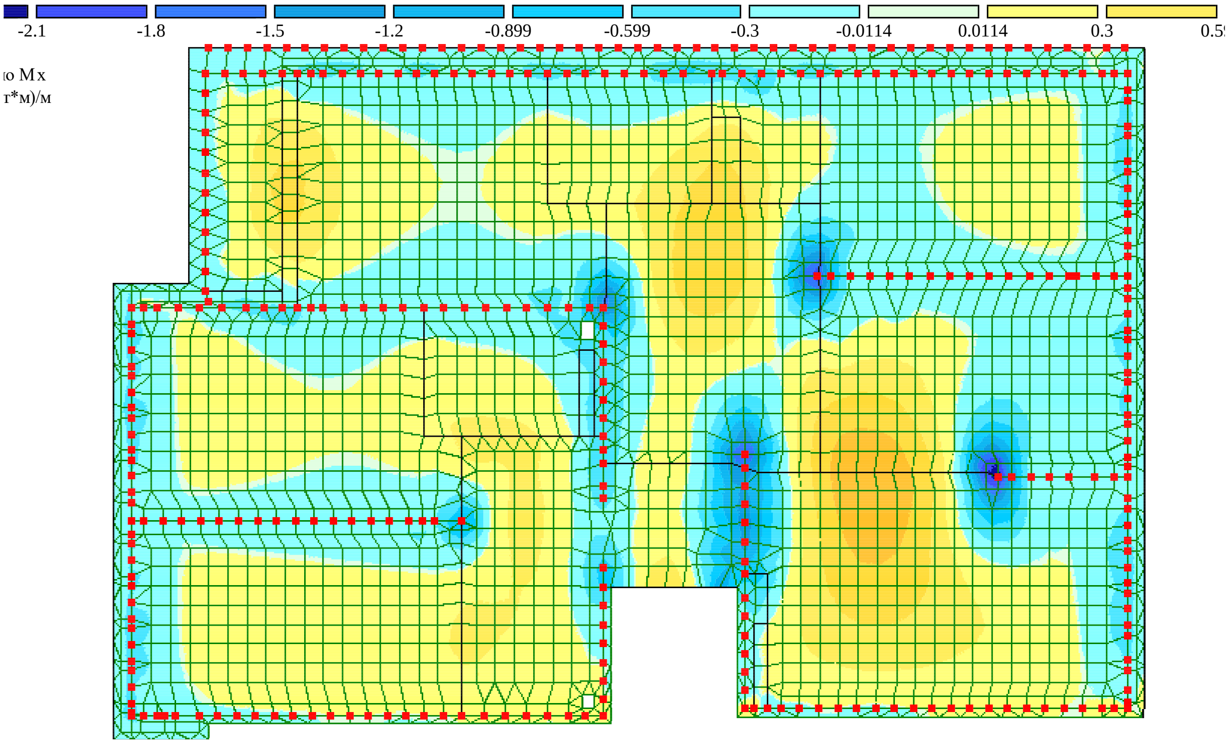


Figure 9. Isofields of stresses by M_x in the case of a separate calculation of the floor slab (case 3)

However, comparing the values of stress mosaics in the same span and on the same support after performing the DCL calculation (see Fig. 10-15), where the areas under consideration are highlighted by squares), differences in the results were revealed by 5 -45% depending on the segment in question.

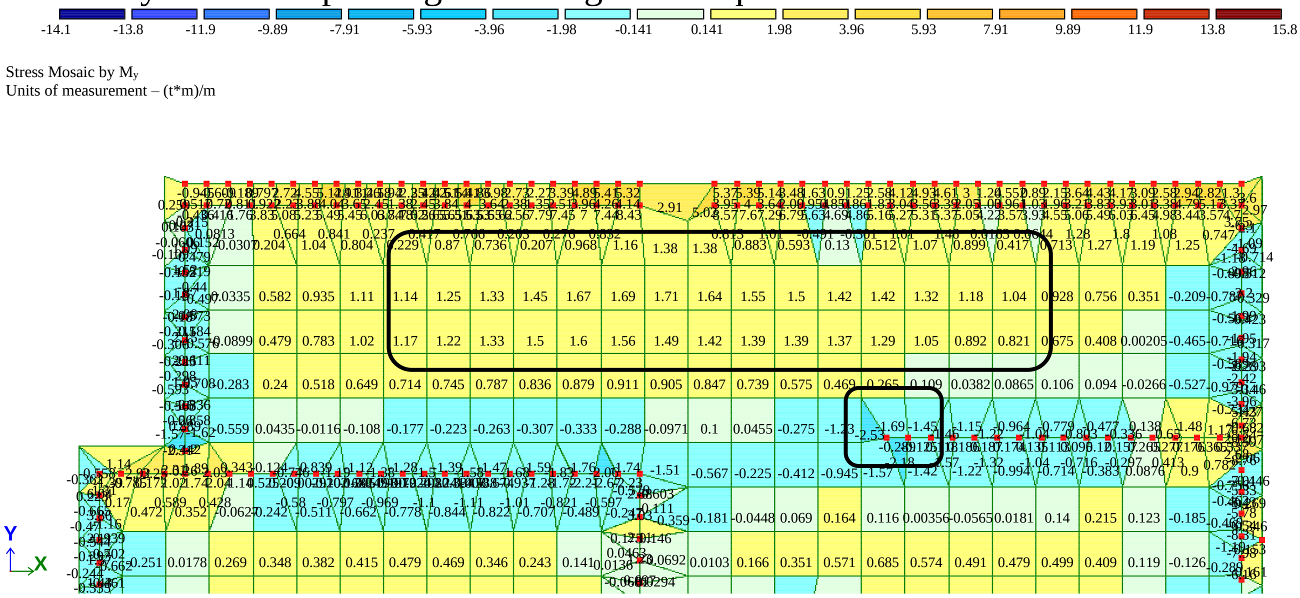


Figure 10. Part of the stress mosaic according to M_y in the case of calculating the floor slab as part of the building frame (case 1)

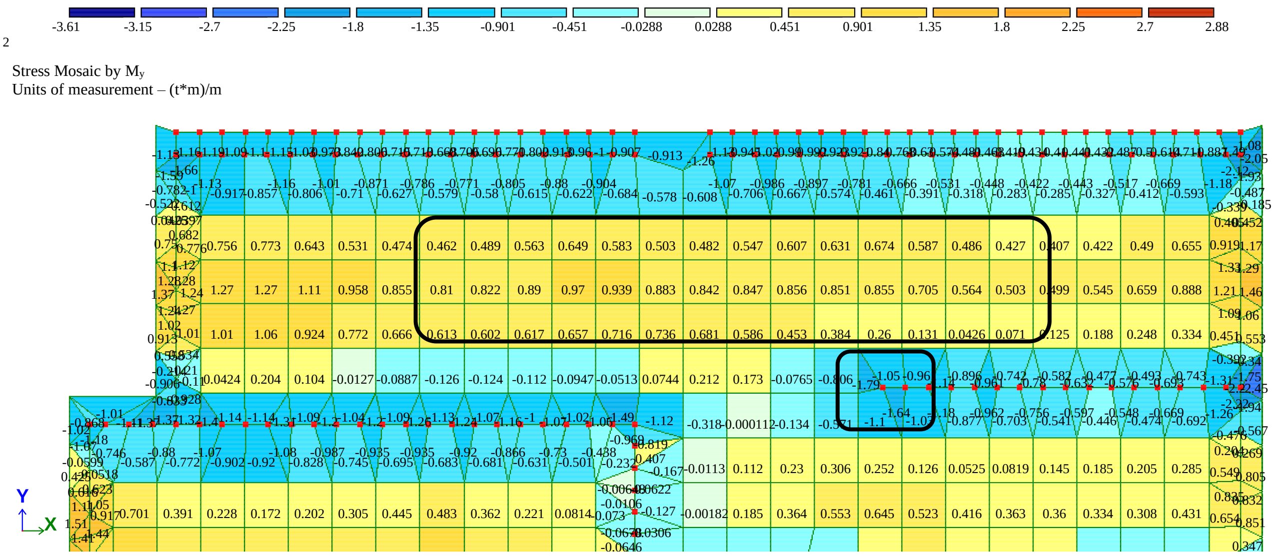


Figure 11. Part of the stress mosaic according to M_y in the case of cutting out a floor slab from the building frame (case 2)

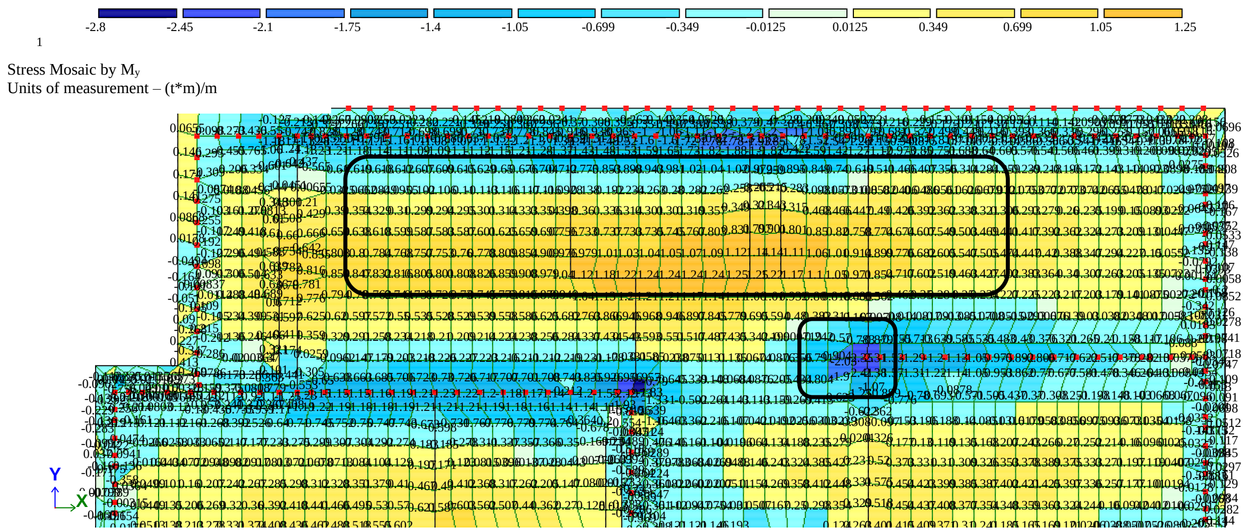


Figure 12. Part of the stress mosaic by M_y in the case of a separate calculation of the floor slab (case 3)

Table 1

Percentage difference in results of maximum stresses according to M_y

Sector	Number of cases	Mx_{max}, t×m	Percentage difference
1	2	3	4
Span	Case 1	1,56	12,1%
	Case 2	0,97	
	Case 3	1,37	37,8%
Support	Case 1	-2,53	5,1%
	Case 2	-1,79	
	Case 3	-2,40	29,2%

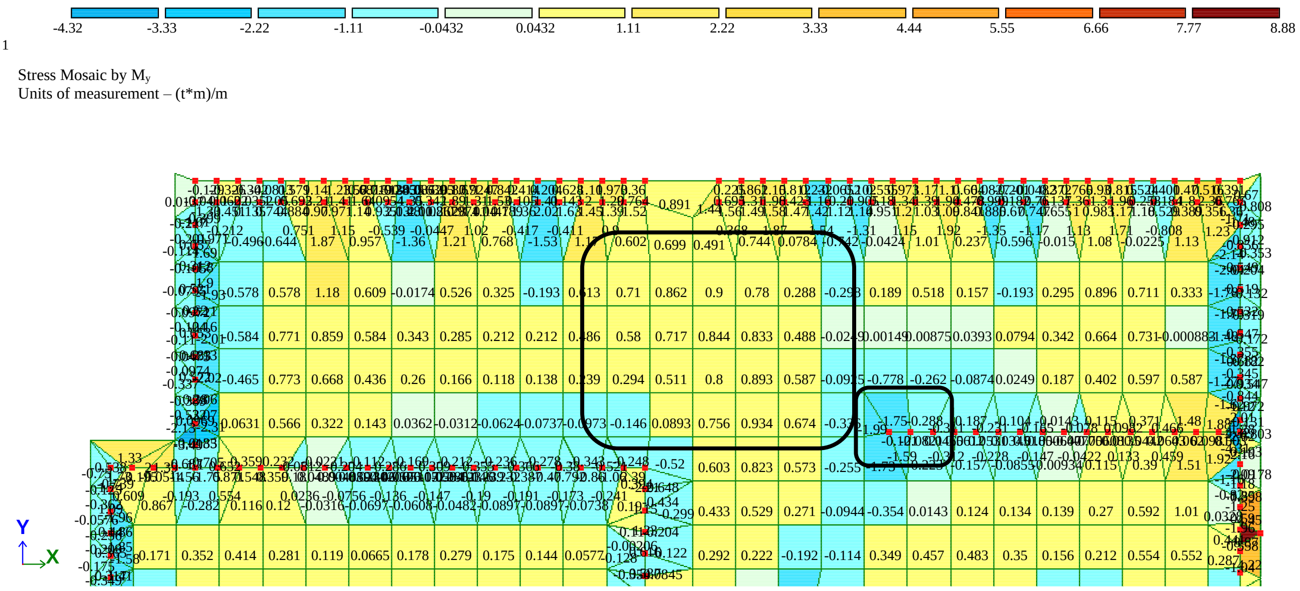


Figure 13. Part of the stress mosaic by M_x in the case of calculating the floor slab as part of the building frame (case 1)

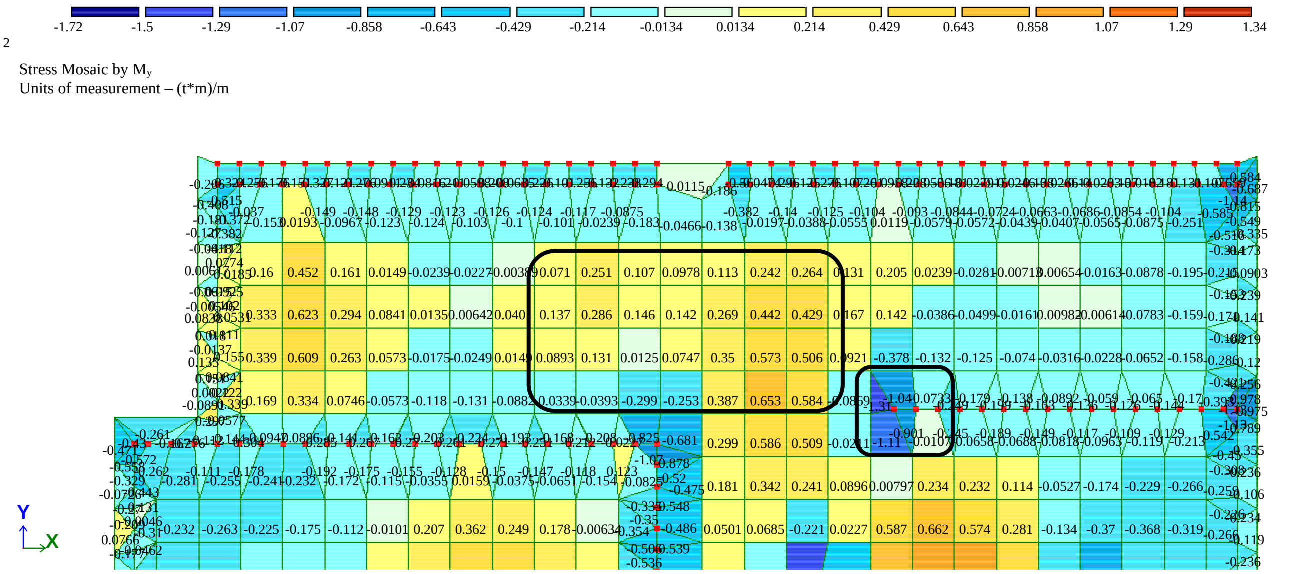


Figure 14. Part of the stress mosaic by M_x in the case of cutting a floor slab from the building frame (case 2)

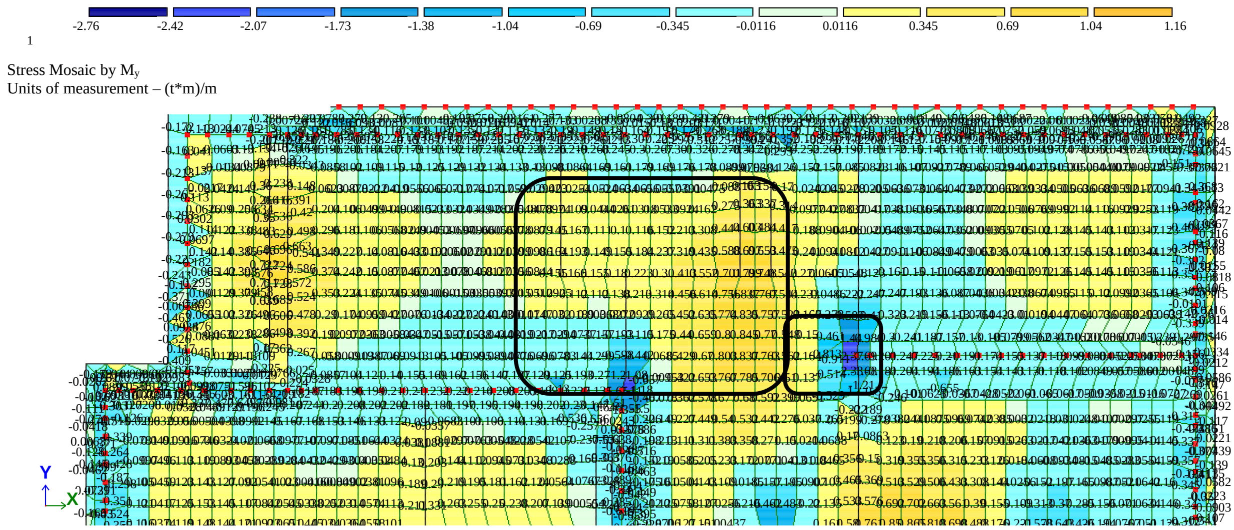


Figure 15. Part of the stress mosaic by M_x in the case of a separate calculation of the floor slab (case 3)

Table 2

Percentage difference in the results of the maximum stresses in M_x

Sector	Number of cases	Mx_{max}, t×m	Percentage difference
1	2	3	4
Span	Case 1	0,93	8,6%
	Case 2	0,65	
	Case 3	0,85	30,1%
Support	Case 1	-1,99	14,6%
	Case 2	-1,31	
	Case 3	-2,33	43,8%

Despite different approaches to solving the problem, the difference in results should not exceed 10-15%.

A possible reason for the occurrence of significant differences in the results of stresses in the first and second calculation cases can be called a combination of factors, such as:

• the difference in the deformability of the supports (case 1 - the supports are deformable frame structures, cases 2 and 3 are absolutely fixed supports);

• insignificant differences in the value of the acting loads in cases 1 and 2 from case 3;

• the difference in the formation of the grid of nodes, namely, in the division of the plate elements into segments and the difference in the size of the step of the grid of nodes.

However, even considering the factors listed above, it is difficult to say for sure what caused the large differences in results. Just as it is impossible to say in which of the options the results are less accurate or incorrect, since there are restrictions on the use of one or another calculation method, as well as recommendations regarding the compilation of design schemes both for the building frame as a whole and for its individual parts using software there are practically no complexes for excluding such contradictions.

If we turn to the rules and regulations, the requirements and assumptions for performing calculations using software systems can be found in SP 267.1325800.2016 “High-rise buildings and complexes. Design rules "for other types of buildings, there are no such regulatory recommendations.

Articles, works and methodological instructions on the use of the software systems themselves also practically do not give precise descriptions and recommendations for drawing up calculation schemes during design.

At the same time, in connection with the improvement of software systems, developers are currently submitting publications, from which it often follows that to improve the accuracy of the results, it is worth using more automated methods for performing calculations and abandoning the classical ones in the case of using software systems. But still, the main idea of such works is to show the capabilities of the developed product, and not to analyze the cases in which there is a need to use them.

An example is the article by the SCAD Office PC developers [2], which describes the technology for constructing computational models and it is supposed to analyze the comparison of the results for the classical model of building the frame, and the model in more detail, built in the latest, at the time of the article's release, version of SCAD (see. fig. 16).

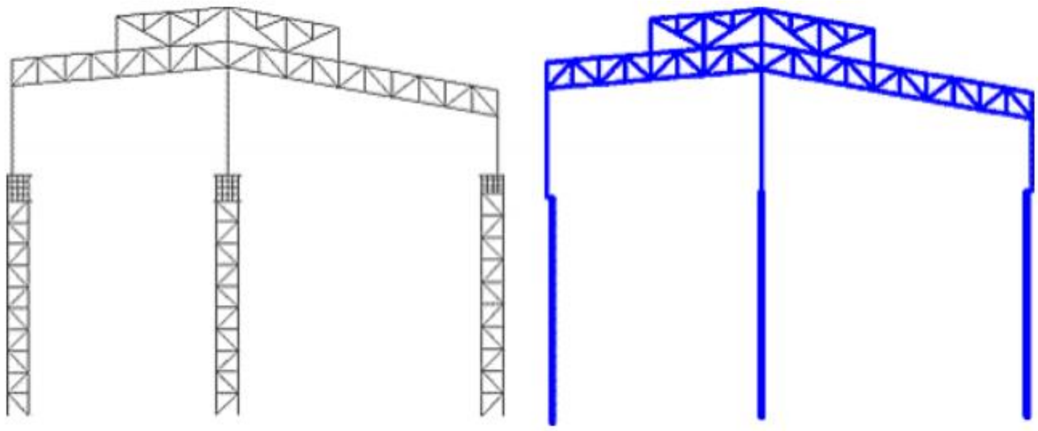


Figure 16. Models for calculating columns. Model No. 1 (left) is presented in the article; model number 2 - classic

The authors of the article describe in sufficient detail the capabilities of one of the versions of the program and the quality of elaboration of the calculation scheme, while the result of the comparison characterizes the level of automation in both cases. At the same time, there are no numerical confirmation of the advantages of a more detailed study of the design model of the frame regarding the accuracy of the results and conclusions about the need to replace the classical method of constructing the design of the frame (see Fig. 17).

Nevertheless, the need to analyze design schemes in software systems in order to identify criteria for their construction in order to obtain the most accurate results is becoming an urgent problem.

Another factor indicating the need to study the characteristics of compiling design schemes, determining the degree of correctness of the results, as well as identifying clear methods of work in the design PCs when calculating them is the increased attention of expert services to the quality of design justifications for design solutions of building structures.

	Type of work or inspection	The degree of calculation automation when using model № 1	The degree of calculation automation when using model № 2
1	Setting the stiffness characteristics of elements	Full automation by selecting a section from the catalog of rolled metal or setting using parametric sections	Calculation of the given stiffness characteristics "manually" or using the section designer, followed by their numerical assignment
2	Deformation check	Full automation	Full automation
3	Checking the strength, stability of the branches between the lattice nodes and the stability of the entire column from the plane of bending	Full automation	Receiving the DCS in the form of M, N, Q, followed by "manual" verification of strength and stability
4	Checking the strength and stability of the lattice elements against the acting loads	Full automation	Receiving the DCS in the form of M, H, K with subsequent "manual" calculation of the forces in the lattice elements and "manual" verification of their strength and stability
5	Checking the ultimate flexibility of lattice branches and elements	Full automation	Completely "manual" calculation or calculation using the "Crystal" program
6	Checking the strength of the grating for Q_x in accordance with clause 5.8 of SNiP II -23-81 *	Completely "manual" calculation	Completely "manual" calculation
7	Checking the overall stability of a two-branch column in the bending plane as a whole bar	Completely "manual" calculation according to the DCS values obtained when calculating the loads on the foundations, and the calculated length calculated according to SNiP	Completely "manual" calculation according to DCS values and calculated length calculated according to SNiP

Figure 17. Comparison of the degree of automation for different methods of constructing computational models

Based on this, as a measure of improving the quality of design justifications for design decisions, Glavgosexpertiza of Russia in 2004 made a proposal: "... to carry out calculations for at least two certified, independently developed and tested in practice software systems, to carry out a comparative analysis of the results" [3].

However, when using this approach to analyze the results, designers may face the fact that the calculation results in different PCs can be radically different.

As a rule, the occurrence of such a problem increases with insufficiently correct use of software systems, since various software systems may have different capabilities and each PC is characterized by its own characteristics.

Therefore, it is not always possible to be guided by the same calculation methods when constructing a design scheme of the same building in different PCs. This can lead to the assumption of miscalculations, which is confirmed by the analysis of a number of emergencies and failures that occurred during the construction and operation of buildings and structures due to insufficiently reliable solutions to their supporting structures.

Currently, it is necessary to understand the specifics of the operation of various software systems, since when conducting an examination in world and domestic practice, they are often asked to provide a comparison of the results of calculating the strength, stability and vibrations of the same object using independently developed and tested PCs.

The use of this technology requires:

• the presence of at least two PCs and the ability to use both PCs professionally;

• repeated description of the computational model for the second PC;

• correct interpretation of discrepancies in the calculation results that may arise, inter alia, due to subjective errors in setting the initial data.

Conclusions

In the course of the analysis of the execution of calculations of building structures using a PC, it became obvious that the need to determine the criteria and draw up general recommendations for the construction of design schemes of buildings, depending on the various characteristics of the frame, is an urgent task.

Despite the active development of software systems with improved capabilities and additional functions embedded in them, one should think about the accuracy and correctness of the calculated results when using them. It is necessary to compare the classical methods of performing calculations and the proposed methods at the present time with the need to carry out a detailed study of the calculations.

Nevertheless, when conducting experiments, one should not forget about the conclusions and simplifications in the implementation of building structures, which were revealed by previous experience and knowledge of the behavior of supporting systems. Under which it was determined that the numerical model should be considered as an idealization.

At the same time, a simplified model should consider important factors and neglect less significant ones. Significant factors that can influence the choice of a numerical model include: geometric properties (structural configuration, dimensions, cross-sections, deviations, defects and expected deformations; material properties (strength, basic relationships, tension versus time, plasticity, moisture dependence on temperature); effects (direct and indirect, variability in time, space, static or dynamic).

Thus, research should be carried out to highlight cases with the possibility of using simplifications, as well as cases of constructing design schemes in which more detailed constructions should be applied.

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