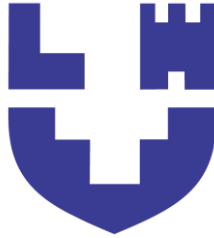


Ministry of Education and Science of Ukraine  
Lutsk National Technical University



## **CAD in Construction**

Methodological instructions for independent work  
for applicants of the first (bachelor's) level of higher education  
of the educational and professional program "Construction and  
Civil Engineering"  
of the field of knowledge 19 Architecture and Construction of  
the specialty 192 Construction and Civil Engineering of full-  
time and part-time forms of study

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The methodological development includes thematic planning of students'  
independent work, questions for self-control, tasks for independent study, and  
recommended literature for working within the LIRA-FEM and MONOMAKH-SAPR  
software complexes.

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## INTRODUCTION

The use of advanced information technologies is key to successful calculations at the design stage of new buildings and structures, as well as when assessing the bearing capacity of existing ones. Currently, there are numerous automated software packages. The results obtained with their help allow for significantly improving the quality and speed of solving relevant engineering problems.

The adoption of technically sound and supported by appropriate calculations of structural solutions is the most important stage of design. Therefore, it is of great importance for higher education students to master modern automated design tools for calculating the strength, stability, rigidity, and design of building structure elements.

The course "CAD in Construction" of the educational and professional program "Construction and Civil Engineering" of the field of knowledge 19 Architecture and Construction, specialty 192 Construction and Civil Engineering teaches the basics of practical work with the design and computing complexes LIRA-FEM and MONOMAKH-SAPR. This methodological development is intended to assist higher education students in completing laboratory tasks from this course and contains algorithms for calculating and designing reinforced concrete and metal structures in the environment of the LIRA-FEM and MONOMAKH-SAPR PCs.

## Course Objectives

The purpose of teaching the academic discipline "CAD in Construction" is to prepare higher education applicants for professional activity in the field of construction design in the conditions of modern information technologies.

The objectives of the course are for students to acquire the necessary knowledge about modern computer-aided design (CAD) systems in construction and to obtain practical skills in design work on the calculation and design of building structures, buildings, and structures in the environment of design and computing complexes LIRA-FEM and MONOMAKH-SAPR.

After completing the course, the student must know:

- principles of designing elements of building structures;
- methods of selecting and checking reinforcement of reinforced concrete elements;
- basic provisions of calculating and designing steel structures.

The student must be able to:

- perform design work in the construction industry using design and computing complexes LIRA-FEM and MONOMAKH-SAPR;
- calculate, design, investigate construction objects;
- use the necessary computer software products in work;
- apply the basic principles, theories and methods of structural mechanics to calculate elements of buildings and structures under the action of loads and influences of various nature, taking into account their interaction, using automated design systems;
- calculate and design reinforced concrete (monolithic and prefabricated), metal and wooden structures using the requirements of regulatory documents, providing reliable and economically justified design solutions;
- Calculate and design load-bearing structures of reinforced concrete, metal, and wooden structures, including using modern information technologies.

# **Content Module 1. Computer-aided implementation of the calculation and design of structures of buildings in the LIRA-FEM**

## **Topic 1. Introduction to the LIRA-FEM**

### **Topic content:**

The goal and objectives of the course on training higher education students for professional activity in the field of construction design in the conditions of modern information technologies. Ribbon interface of the PC LIRA-FEM. General algorithm for calculating building structures.

### **LIRA- FEM ribbon interface**


The ribbon interface of the LIRA-FEM contains the following main components: tabs, contextual tabs, panels, and menus.

A tab is an element of the graphical user interface that allows you to switch between certain sets of interface elements in one window.

**Contextual tabs** (Nodes, Bars, Plates) appear when nodes and elements are selected and disappear after they are deselected.

The **Quick Access Toolbar** (Figure 6) is located at the top of the ribbon and provides direct access to a specific set of commands. The bar is customizable and contains a set of commands that are independent of the tab currently displayed on the ribbon.

**Program menu** – a menu for working with document files and setting units of measurement, interface language, and parameters for graphical display of the scheme and calculation results. This command is called by

clicking on the button . The main page of the menu (on the right) displays a list of documents that were opened recently.

The program menu contains operations that provide work with files used by VIZOR-SAPR. To manage the task as a whole, commands collected in the program menu are used. The menu consists of two panels: the left one displays groups of commands for working with files, and the right one displays a list of commands in the selected group.

Thus, the **New group** – a group of commands for creating a new problem file – contains commands for specifying the schematic characteristics:

- the first schema characteristic – two degrees of freedom in the node (displacement X, Z) XOZ;
- the second schema characteristic – three degrees of freedom in the node (displacement X, Z, Uy) XOZ;
- the third schema characteristic – three degrees of freedom in the node (displacement Z, Ux, Uy) XOY;
- the fourth schema characteristic – three degrees of freedom in the node (displacement X, Y, Z);
- the fifth schema characteristic – six degrees of freedom in the node (displacement X, Y, Z, Ux, Uy, Uz).

Another important group of commands – **Settings** – allows you to change the program settings (units of measurement, scale parameters, colors, calculation parameters, number and font formats, and interface language).

**Status bar** – panel at the bottom of the window, designed to display

tips for menu items and display elements, and also contains blocks for loading the calculation scheme and loading the analysis (in the results analysis tabs) and a block for construction.

### **General algorithm for calculating structures**

1. Creating a file (the name must contain up to 30 characters), selecting the design scheme feature, comments.
2. Setting up the program (units of measurement, interface language, main panels).
3. Selecting the cross-section calculation option (based on efforts from individual loads, RSZ or RSN). Selecting the design option:
  - for reinforced concrete structures – according to DBN V.2.6-98:2009. Structures of buildings and structures. Concrete and reinforced concrete structures. Basic provisions;
  - for MK – according to DBN V.2.6-198:2014. Steel structures. Design standards.
4. Creating a geometric diagram of the structure.
5. Setting boundary conditions.
6. Creating and assigning stiffnesses.
7. Visual 3D control.
8. Specifying loads.
9. Static calculation of the structure.
10. Analysis of the results of the static calculation.
11. Purpose of materials:
  - for reinforced concrete – type, concrete, reinforcement;
  - for reinforced concrete – material, additional characteristics, selection restrictions.
12. Full calculation (static and structural).
13. Review and analysis of the results:

- for reinforced concrete – selection of reinforcement,
- for reinforced concrete – checking and selection of sections.

**List of literary sources: [1], p. 7-18; [9], p. 250-263.**

**Questions for self-control:**

1. What is the LIRA-FEM PC intended for?
2. The capabilities of the LIRA-FEM PC.
3. The main components of the LIRA-FEM PC ribbon interface.
4. How to set the units of measurement in the LIRA-FEM PC?
5. What loads should be calculated for the structures of buildings and structures?
6. General algorithm for calculating structures in the PC.

**Topic 2. Calculation and design of a reinforced concrete beam**

**Topic content:**

Calculation of a reinforced concrete beam with a rectangular section of dimensions  $b \times h$ , a span of  $L$ , made of concrete of class  $C$ , reinforced with longitudinal reinforcement of class  $A$ , loaded with a uniformly distributed load along the length with an intensity  $q$  (kN/m). Analysis of the calculation results.

The initial data is taken from Table 1 by the serial number in the group list.

Table 1. Initial data for beam calculation

The last digit of the cipher	Flight L, m	Beam cross-section b x h, cm	Penultima te digit of the cipher	Concrete class	Reinforce ment class	Running load q, kN/m
0	6	25x50	0	C20/ 25	A400C	25
1	7	30x50	1	C25/30	A500C	28
2	8	35x60	2	C30/ 35	A400C	30
3	9	38x65	3	C25/ 30	A500C	32
4	12	40x80	4	C20/ 25	A400C	42
5	6	25x45	5	C30/ 35	A500C	20
6	7	32x64	6	C25/ 30	A400C	26
7	8	35x70	7	C20/ 25	A500C	34
8	9	35x75	8	C30/35	A500C	35
9	10	40x70	9	C25/ 30	A500C	40

**List of literary sources: [1], p. 19-35; [9], p. 270-288.**

**Questions for self-control:**

1. Sequence of creation of the calculation scheme.
2. Static calculation of structures in PC LIRA-FEM.
3. Basic commands.
4. Analysis of calculation results.
5. Report generation.

**Topic 3. Calculation and design of reinforced concrete slabs**

**Topic content:**

Calculation and design of a monolithic reinforced concrete flat floor slab with dimensions BxL, thickness h. The slab is freely supported by its

shorter sides on the walls. The calculation is performed according to the RSZ for the following loads:

- ✓ load 1 – self-weight of the slab;
- ✓ load 2 – quasi-permanent, evenly distributed over the entire area of the slab  $q_2$  (kPa);
- ✓ load 3 – short-term, evenly distributed over the entire area of the slab  $q_3$  (kPa).

The initial data is taken from table 2 by the serial number in the group list.

Table 2. Initial data for slab calculation

The last digit of the cipher	Plate thickness cm	Slab dimensions BxL, m	Penultima te digit of the cipher	Concrete class	Reinforcement class	Load $q, \text{kN/m}^2$	
						$q_2$	$q_3$
0	18	3x6	0	C20/ 25	A400C	2.5	12
1	19	3.5x7	1	C25/30	A500C	2.8	14
2	20	4x8	2	C30/ 35	A400C	2.0	16
3	16	3x5.5	3	C25/ 30	A500C	2.2	15
4	17	3.5x6	4	C20/ 25	A400C	3.0	10
5	15	2.5x4.5	5	C30/ 35	A500C	1.0	8
6	16	3x6.5	6	C25/ 30	A400C	1.6	9
7	20	3.5x8	7	C20/ 25	A500C	2.4	14
8	19	3x6	8	C30/35	A400C	2.6	15
9	20	4x7	9	C25/ 30	A500C	3.2	16

**List of literary sources: [1], p. 35-58; [6], p. 32-51; [9], p. 289-314.**

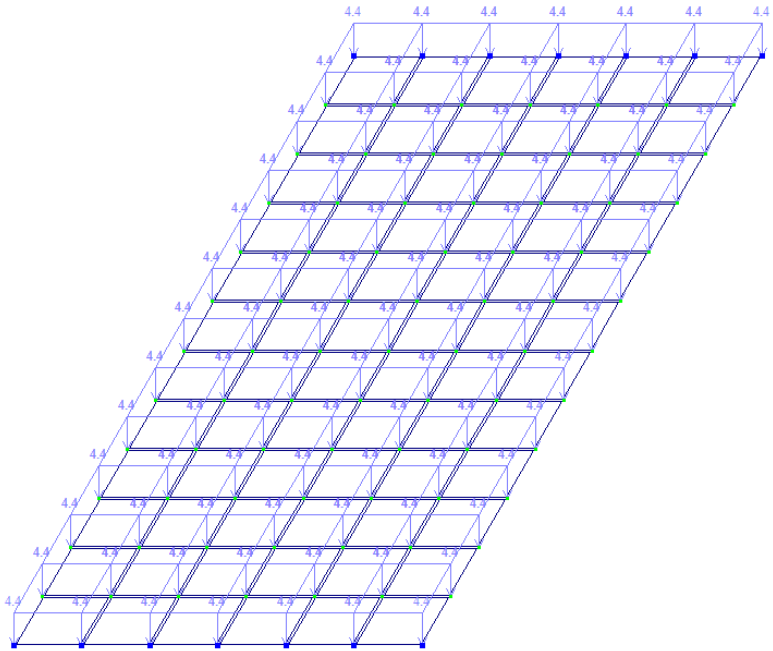


Fig. 1. Calculation diagram of the slab

**Questions for self-control:**

1. What feature of the scheme should be selected for the calculation of the slab?
2. What finite elements are used when building the calculation scheme of the structure?
3. Modeling loads on the slab.
4. How to generate a table of DCF?
5. What commands are used to analyze the results of the static calculation of the slab?
6. What data should be specified for the calculation of the reinforcement of

the slab?

7. How to create a table with the results of the selection of reinforcement?
8. How to display the results of the selected reinforcement in a specific element of the slab?
9. Features of the design of the slab.

#### **Topic 4. Calculation of a reinforced concrete frame of a multi-story building. Design of columns and beams**

##### **Topic content:**

Calculation of a transverse reinforced concrete frame (Fig. 2) for static loads (Fig. 4). Analysis of the results of static calculation. Design of frame elements - columns and beams.

Perform the calculation for the following loads:

- first - from the own weight of the structures;
- second - snow (uniformly distributed on the coating) -  $q_2$  (kN/m);
- third - from the weight of the equipment (uniformly distributed on the floors in the extreme spans) -  $q_3$  (kN/m);
- fourth - from the weight of the equipment (uniformly distributed on the floors in the middle spans) -  $q_3$  (kN/m);
- fifth - wind from the right -  $P_1$  ;  $P_2$  (kN/m).

Form each load separately.

The initial data for constructing the design scheme of the frame should be taken from Table 3 by the serial number in the group list. The load values should be selected from Table 4.

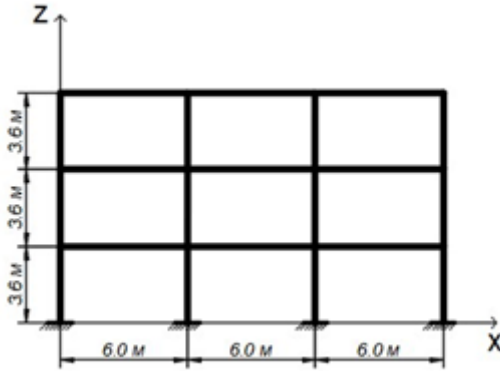


Рис. 2 – Схема рами

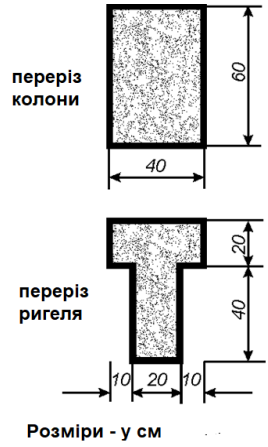


Рис. 3 – Перерізи елементів рами

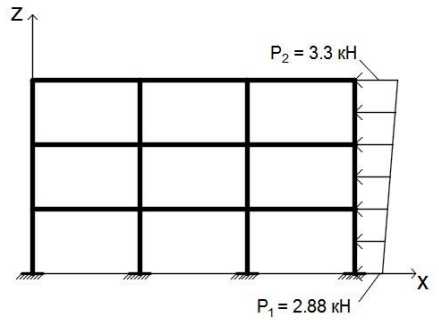
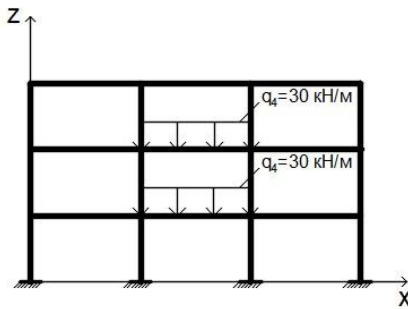
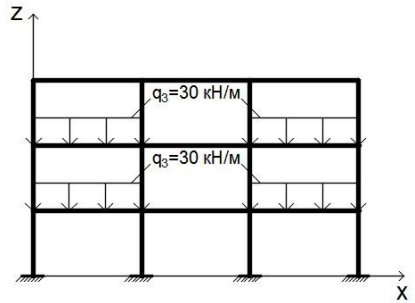
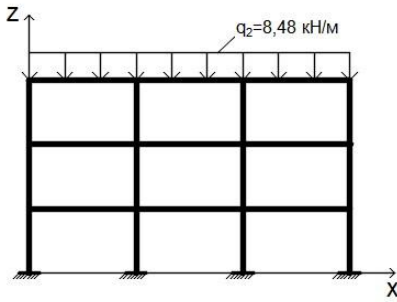


Fig. 4 – Frame loading schemes

List of literary sources: [1], p. 59-88; [6], p. 7-31; [9], p. 315-346.

**Questions for self-control:**

1. What feature of the scheme should be chosen for the calculation of a flat frame?
2. How to model the load from the self-weight of the frame elements?
3. How to model the wind load?
4. Why is it necessary to generate a table of DCF for structural calculation?
5. Features of the design of columns and beams.

Table 3. Initial data for calculating the frame

The last digit of the cipher	Beam span	Number of spans	Story height	Number of floors	Penultima te digit of the cipher	Column material	Column cross-section ■	Beam material	Beam cross-section T
0	6 9	2 1	4.7 4.2	1 3	0	C16/ 20	40x40	C20/ 25	25x70x x60x25
1	6 12	3 1	3.6 7.2	3 1	1	C20/ 25	40x50	C25/ 30	30x80x x60x30
2	9 6	3 1	3.0 6.0	2 1	2	C25/ 30	40x40	C30/ 35	25x75x x60x30
3	6 9	3 1	4.2 3.6	1 3	3	C20/ 25	30x40	C25/ 30	30x70x x60x30
4	6 12	4 1	7.2 3.6	1 4	4	C16/ 20	40x40	C20/ 25	20x75x x60x30
5	12 6	2 1	4.8 7.2	2 1	5	C25/ 30	40x50	C30/ 35	30x80x x65x30
6	9 6	2 2	6.0 4.2	3 1	6	C20/ 25	40x40	C25/ 30	25x70x x60x30
7	6 4.8	4 1	4.2 3.0	4 2	7	C16/ 20	30x40	C20/ 25	20x60x x50x20
8	6 9	3 2	3.6 4.8	4 1	8	C25/ 30	40x50	C30/ 35	25x75x x65x30
9	12 6	4 1	7.2 3.6	2 2	9	C20/ 25	40x60	C25/ 30	30x80x x65x30

Table 4. Frame loads

Load	The last digit of the code									
	1	2	3	4	5	6	7	8	9	0
q <sub>2</sub>	6.2	6.4	6.6	6.8	6.9	7.0	7.2	7.4	7.6	7.8
q <sub>3</sub>	20	16	26	18	24	20	25	30	24	28
P <sub>1</sub>	1.5	1.4	1.2	1.0	1.3	1.4	1.2	2.2	1.8	1.6
P <sub>2</sub>	1.9	1.8	1.6	1.5	1.7	1.8	1.7	2.6	2.2	2.0

**Topic 5. Design a monolithic beam floor slab. Design a slab and secondary beam**

**Slab Design**

**Topic Content:**

Calculation of monolithic floors for static loads. Analysis of static calculation results.

The spatial model is shown in Fig. 5. The floor material is class C concrete, reinforcement is made of individual rods of class A(B) reinforcement. The initial data for constructing the calculation scheme is taken from Table 5 by the serial number in the group list.

For detailed instructions on design, floor layout, determination of design spans and loads, see [1].

The calculation is performed for two loads:

- the first load is constant, uniformly distributed  $g$ , kN/m<sup>2</sup> (including self-weight);
- the second load is variable (long-term) uniformly distributed  $p$ , kN/m<sup>2</sup>.

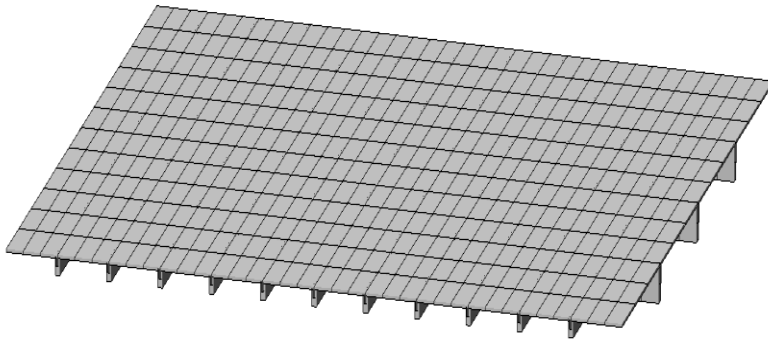


Fig. 5 – Spatial model of beam floor

Table 5. Initial data for the calculation of the beam floor

The last digit of the cipher	Plate thickness cm	Slab dimensions BxL, m	Penultimate digit of the cipher	Concrete class	Reinforcement class	Linear load, kN/m	
						$q$	$p$
0	7	18x24	0	C16/20	A400C	2.5	6.2
1	8	18x30	1	C20/25	A500C	2.8	6.4
2	7	24x30	2	C12/15	A400C	3.0	6.6
3	8	12x18	3	C16/20	A500C	2.2	6.8
4	9	18x18	4	C20/25	A240C	2.0	7.0
5	7	24x24	5	C12/15	A400C	1.8	7.2
6	8	12x24	6	C16/20	A240C	1.6	7.4
7	6	18x30	7	C20/25	A500C	2.4	7.6
8	7	30x30	8	C12/15	A400C	2.6	7.8
9	10	24x18	9	C25/30	A500C	3.2	8.0

Note. The class of the slab reinforcement should be taken as B500.

### Design Guidelines

Flat reinforced concrete floors are divided into beam and beamless. Beamless floors consist of beams located in one or two directions and a slab that supports them. Beamless floors consist only of a slab that supports directly on columns.

When composing a design scheme, a slab can be a beam (one that works in one direction) or a slab (one that works in two directions). The criterion for choosing a design scheme for a slab supported along the contour is the ratio of its sides.

The example given considers a monolithic beam floor that consists of a flat slab and a system of cross beams - main and secondary.

The design of reinforced concrete floors is carried out in the following sequence:

1. Layout of the building/structure. At this stage, a structural diagram is developed, the main load-bearing elements are determined, their dimensions are assigned, etc.
2. Static calculation. Based on the adopted structural scheme, a calculation scheme is selected, all loads and influences are determined, and the forces in the system elements are determined.
3. Calculation of sections. According to the acting forces, the dimensions of the elements' cross-sections are selected, or it is checked whether the previously assigned dimensions are sufficient to perceive the forces.
4. Design. Element reinforcement schemes are determined, and drawings of reinforcing and embedded products are created.

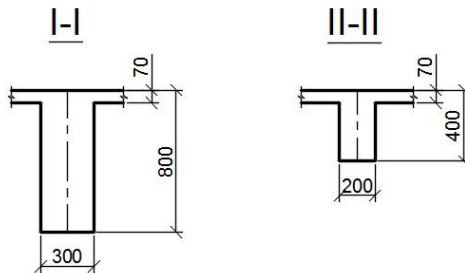
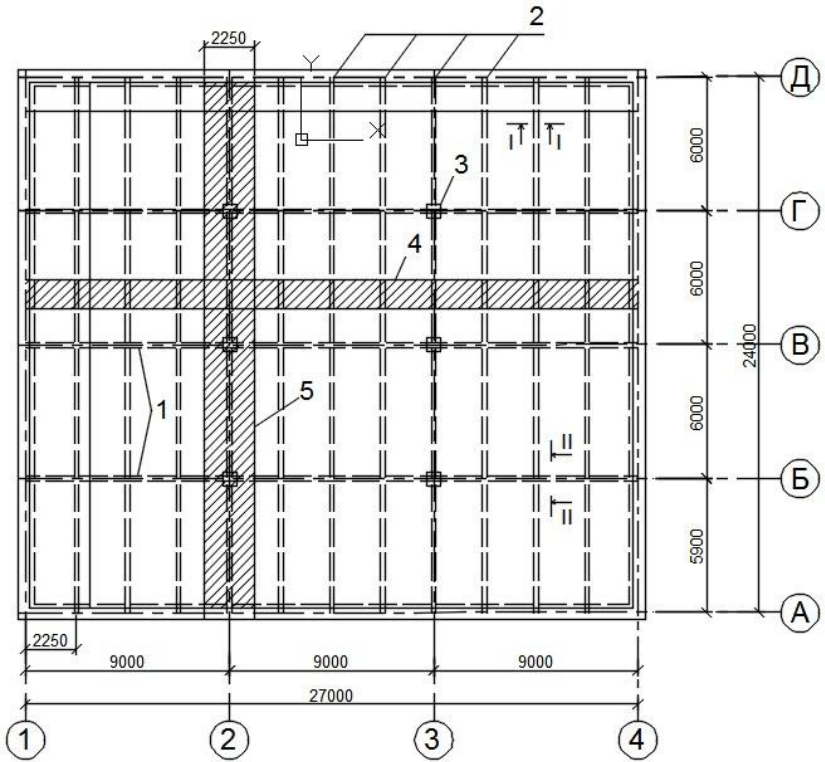


Fig. 6 – To calculate a monolithic ribbed floor with beam slabs:

- 1 – main beam Bm-1; 2 – secondary beam Bm-2; 3 – column Km; 4 – design strip of the slab Pm; 5 – load strip of the secondary beam

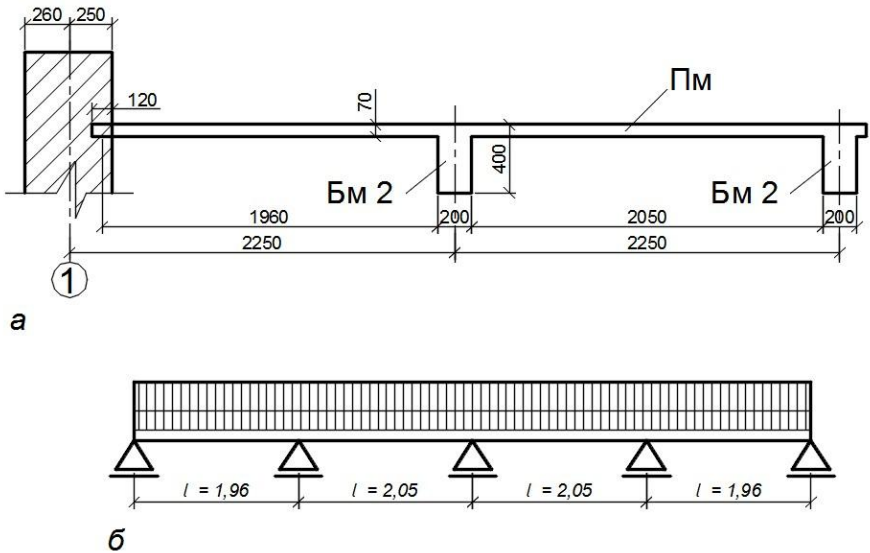


Fig. 7 – Before calculating the slab:  
 a – structural scheme; b – calculation scheme

### 5.1. Design of a beam floor slab

#### Topic content:

Calculation for the selection of reinforcement for slab elements. Analysis of mosaics of lower and upper reinforcement. Selection of working and structural reinforcement of the slab according to the tables of results of automated reinforcement selection

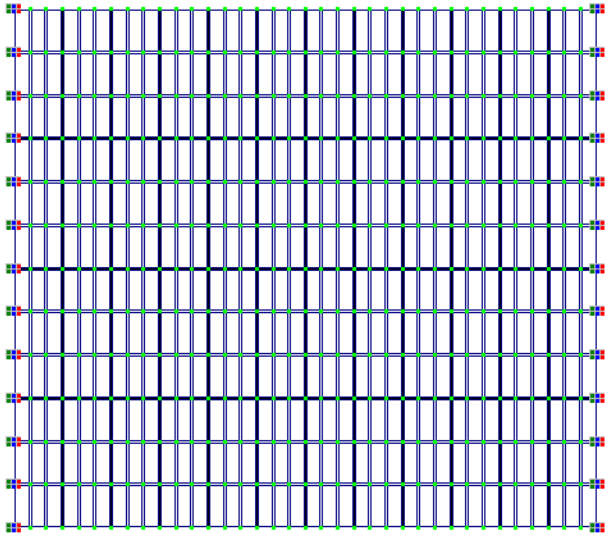
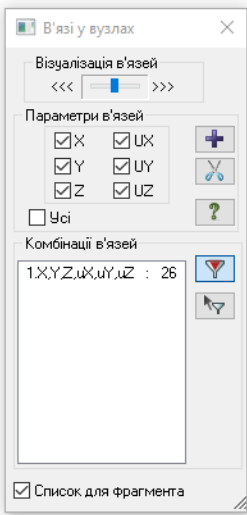


Fig. 8 – Setting the joints on the shorter sides of the slab

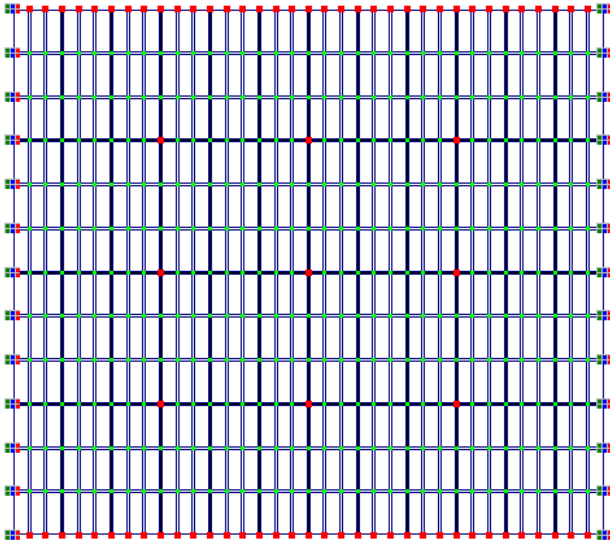
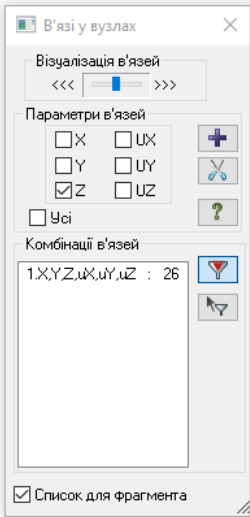


Fig. 9 – Setting of elms in the supporting nodes of the floor

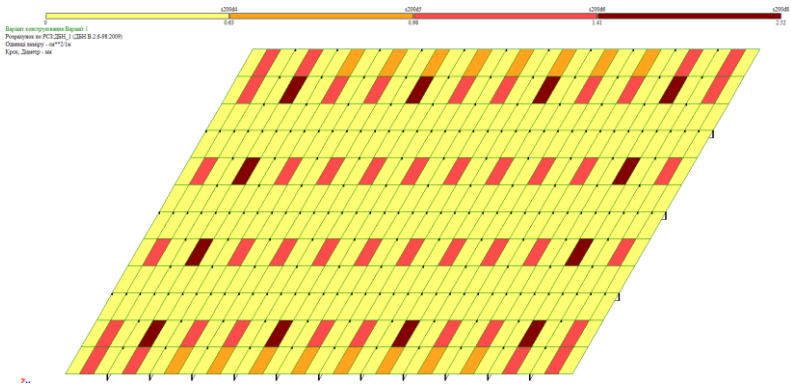


Fig. 10 – Reinforcement area per 1 linear meter along the X1 axis near the bottom edge

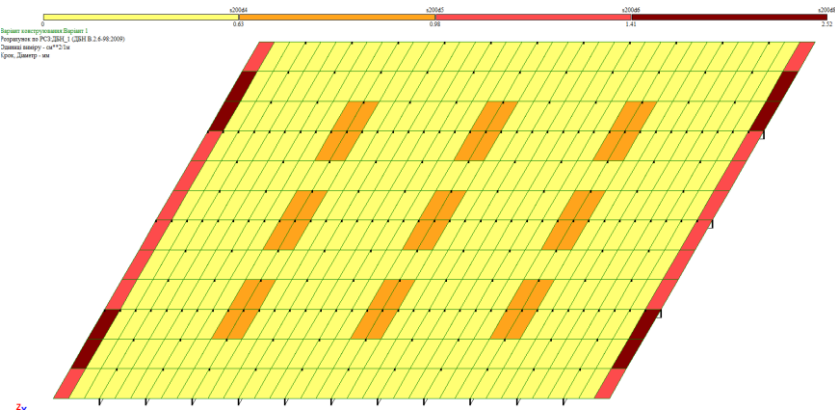


Fig. 11 – Reinforcement area per 1 linear meter along the Y1 axis near the upper edge

**Slab design**

It is worth remembering that in the LIRA-FEM PC the calculation is performed in a linear setting. In the case of reinforcing the slab with separate bars with a slab thickness of up to 120 mm, separate reinforcement is used, i.e. all the bars of the span reinforcement are

brought to the supports, above which their reinforcement is installed. In this case, the lower span bars are designed as through-beams, passing them through several supports, and in the extreme spans, where the calculation requires more reinforcement, additional bars are installed.

According to the tables of the results of the automated selection of reinforcement, the working and structural reinforcement of the slab is selected.

In addition to the main working reinforcement, the installation of over-support reinforcement in the non-working direction is provided near the supports near the walls (to perceive partial pinching moments) and above the main beams. The amount of this reinforcement is taken to be at least  $1/3$  of the span reinforcement of the slab. The length of the supporting rods above the beams (both main and secondary) is determined from the condition that the horizontal sections on each side of the beam face are equal to  $1/4$  of the span of the slab, i.e., 500 mm. The length of the supporting rods near the walls is taken from the condition that the horizontal sections from the wall are equal to  $1/10$  of the span of the slab.

## **5.2. Calculation and design of a secondary beam**

### **Topic content:**

Creation of a calculation model of a secondary beam of a monolithic beam floor. Generation of a table of calculated load combinations (RCN). Static calculation of the beam, visualization of calculation results. Analysis of force diagrams. Selection of reinforcement. Design of the beam. The initial data for the calculation should be taken from clause 5.1.

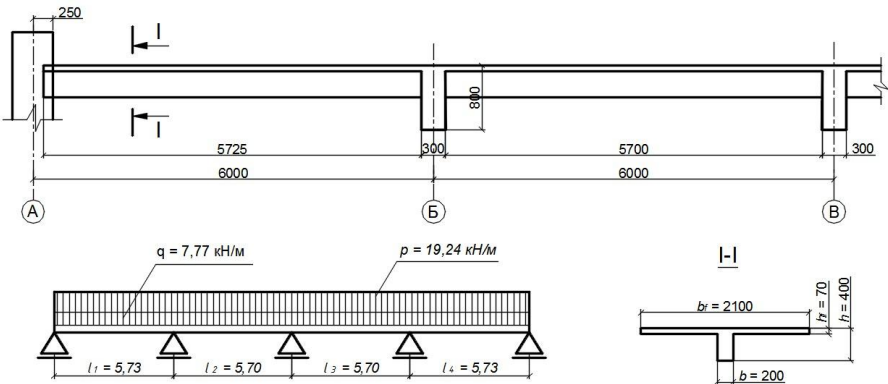


Fig. 12 – Design spans, cross-section and diagram of a secondary beam



Fig. 13 – Design diagram of a beam

List of literary sources: [1], p. 89-119; [4], p. 342-386; [9], p. 347-379.

### Questions for self-control:

1. What feature of the scheme should be chosen for the calculation of a beam floor?
2. What finite elements are used when building a structural calculation scheme?
3. How are main and secondary beams modeled?
4. How to display a 3D model of a structure?
5. How to specify rigid inserts? What are they for?
6. How to assign material parameters for structural calculation?

7. How to display the areas of longitudinal and transverse reinforcement for plate elements and reinforcement diagrams/mosaics for rod elements on the calculation scheme?

## **Topic 6. Design of metfl trusses**

### **Topic content:**

Calculation and analysis of the stress-strain state of a metal truss.  
Verification and selection of cross-sections of truss elements.

A flat gable truss made of seamless hot-rolled pipes is calculated for the following loads:

- 1 – self-weight of the covering structures;
- 2 – snow load on the entire span,
- 3 – snow load on half the span of the truss.

Make a table of calculated force combinations (DCF) for all elements of the truss. Check and select cross-sections of truss elements according to DCF.

Select the truss scheme (Fig. 14) by the serial number in the group list.

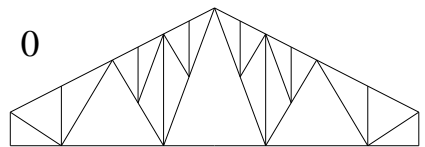
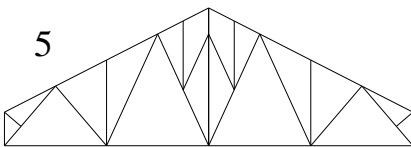
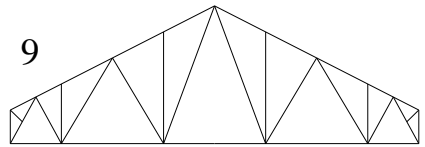
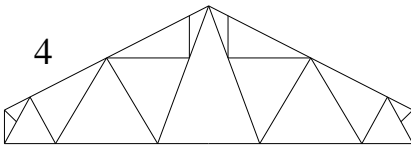
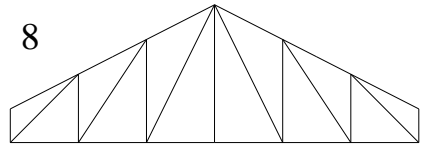
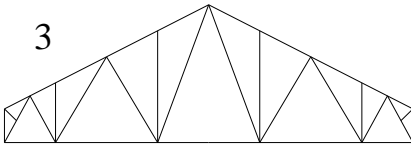
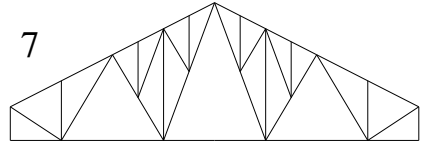
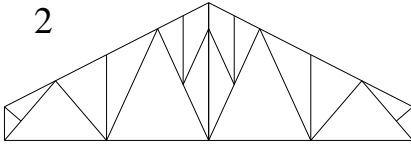
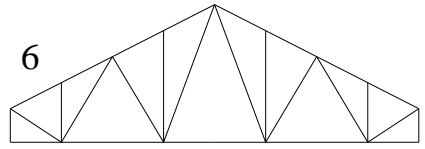
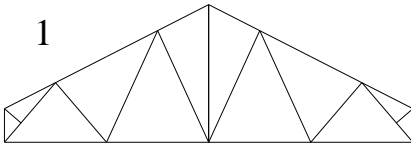


Fig. 14. Truss diagrams

Table 6. Initial data for calculating a metal truss

Penultimate digit of the cipher	Nodal load (kN)			The last digit of the cipher (diagram number)	Truss span (m)	Truss height (m)	Panel length (m)	Slope (degrees)	Upper and lower chord bars	Braces and struts
	P <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>							
1	22	20	20	1	36	3.0	6	12	Pipe 152x6	Pipe 76x5
2	24	22	22	2	24	2.8	3	15	Pipe 140x5	Pipe 68x5
3	26	24	24	3	18	3.2	1.5	18	Pipe 133x6	Pipe 60x4
4	28	25	25	4	30	2.6	6	25	Pipe 146x5.5	Pipe 73x4
5	25	26	26	5	27	3.15	3	30	Pipe 121x6	Pipe 70x5
6	30	22	22	6	36	3.4	6	25	Pipe 159x10	Pipe 83x6
7	32	34	24	7	18	2.7	1.5	18	Pipe 114x5	Pipe 70x4
8	34	25	25	8	24	2.6	3	15	Pipe 127x6.5	Pipe 68x5
9	36	26	26	9	27	3.2	6	12	Pipe 146x6	Pipe 76x4.5
0	38	28	28	10	30	3.0	6	10	Pipe 152x6.5	Pipe 89x6

- load 1 – from its own weight (P<sub>1</sub> - applied along the Z axis to the nodes of the upper truss belt);
- load 2 – snow load for the entire span (P<sub>2</sub> - applied along the Z axis to the nodes of the upper truss belt);
- load 3 – snow load for ½ span (P<sub>3</sub> - applied along the Z axis to the nodes of the upper truss belt).

## Content Module 2. Calculation and design of structures of multi-storey monolithic frame buildings in the MONOMAKH-CAD

### Topic 7. Familiarization with the software complex, its capabilities and interface

#### Topic content:

Introduction to the MONOMAKH-SAPR PC and the programs included in it.

The MONOMAKH-SAPR PC is a typical representative of intelligent design systems. The complex is designed for the calculation and design of structures of monolithic multi-storey frame buildings. The calculation of brick buildings up to 14 floors high with monolithic reinforced concrete inclusions has also been implemented. The MONOMAKH PC consists of nine information-related programs, each of which can operate in an autonomous mode: KOMPONOVKA, BEAM, COLUMN, FOUNDATION, RETAINING WALL, SLAB, SECTION (WALL), BRICK, SOIL. Fig. 15 shows the components of the MONOMAKH-SAPR PC.

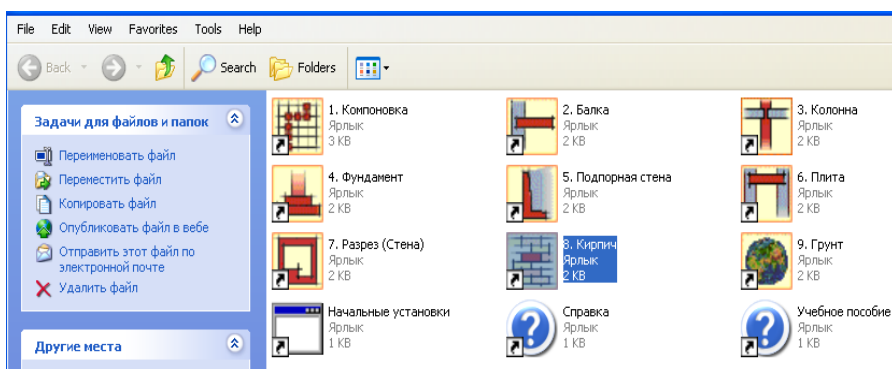


Fig. 15. Components of the MONOMAKH-SAPR PC

**List of literary sources: [1], p. 136-138; [4], p. 668-670.**

**Questions for self-control:**

1. What is the MONOMACH PC intended for?
2. What programs are included in the MONOMACH PC?

**Topic 8. Creating a model and calculating a multi-story monolithic frame building in the KOMPONOVKA program**

**Topic content:**

Creating a model of a multi-story public building according to an individual task. Static calculation. Detailed analysis of the calculation of the main structural elements. Export of results to the MONOMAKH PC design programs.

**Design Guidelines**

KLOPONOVKA is a root program for designing multi-story frame buildings made of monolithic reinforced concrete and buildings with brick walls. It allows you to quickly and conveniently form a building scheme in an interactive graphical mode, specify loads in a natural form, calculate the structural elements of the building for strength, select cross-sections of elements, determine the consumption of concrete, reinforcement, bricks, and other materials, estimate the cost of the structure, and export data to other local programs.

At the first stage of work, the main characteristics of the building are set (planning mark, soil characteristics, and materials of structural elements). After that, a typical floor plan is built, columns (pylons), walls, partitions, existing openings, loads on floor slabs, and coatings are specified.

## Initial data for creating a calculation model

Initial data for designing a building in the KOMPONOVKA program are:

- floor plans (basement, first, typical),
- sections (with height marks),
- information about the structural scheme of the building, the main load-bearing elements (location on the plan, sections and materials),
- dimensions of window and door openings,
- constant and variable loads on floors and coatings,
- construction area (to determine wind and snow loads),
- geological conditions of the construction site.

## Collection of loads

The loads acting on the floors and coverings are constant and variable. The constant characteristic load includes the weight of the floor or roof. The value of the characteristic temporary load is calculated by multiplying the thickness of a certain layer of material by its bulk density (density). The self-weight of a monolithic reinforced concrete floor slab (covering) is taken into account by the program automatically when modeling the calculation scheme, so it is not necessary to specify it again. The calculated values of the loads are calculated by multiplying the standard values by the reliability coefficients for the load action  $\gamma_{fm}$  and for the responsibility class of the structure  $\gamma_n$ . The calculation is reduced to tables.

The characteristic and quasi-constant values of uniformly distributed variable (temporary) loads on the floor slabs (depending on the purpose of

the premises) are given in Table 6.2 [14]).

Characteristic values of loads and impacts (wind and snow loads) for cities in Ukraine are given in Appendix E [14]).

Table 1. Total load per 1 m<sup>2</sup> of floor slab

№	Load name	Characteristic load, kPa	coefficients		Design load, kPa
			$\gamma_{fm}$	$\gamma_n$	
	<i>Permanent load</i>				
1	Ceramic tiles on cement-sand mortar, $\delta = 0,015 \text{ m}, \rho_m = 1900 \text{ кг/М}^3$	0,285	1,1	0,95	0,298
2	Cement-sand screed, $\delta = 0,02 \text{ m}, \rho_m = 1800 \text{ кг/М}^3$	0,360	1,2	0,95	0,410
3	Insulation $\delta = 0,05 \text{ m}, \rho_m = 90 \text{ кг/М}^3$	0,045	1,3	0,95	0,056
4	Cement-sand screed, $\delta = 0,02 \text{ m}, \rho_m = 1800 \text{ кг/М}^3$	0,360	1,2	0,95	0,410
5	Reinforced concrete floor slab, $\delta = 0,16 \text{ m}, \rho_m = 2500 \text{ кг/М}^3$	Load is automatically taken into account by the program			
	Total:	1,05			1,174
	<i>Variable load, including:</i>	1,50			1,710
	quasi-permanent	0,35	1,2	0,95	0,399
	short-term	1,15	1,2	0,95	1,311
	<i>Full load</i>	2,55			2,884

Table 2. Total load per 1 m<sup>2</sup> of coverage

№	Load name	Characteristic load, kPa	coefficients		Design load, kPa
			$\gamma_r$	$\gamma_n$	
	<i>Permanent load</i>				
1	Rolled carpet, $\delta = 0,015 \text{ m}, \rho_m = 600 \text{ кг/М}^3$	0,120	1,1	0,95	0,125
2	Cement-sand mortar screed M100, reinforced with mesh 150x150 diam. 4 Bp-I, $\delta = 0,04 \text{ m}, \rho_m = 1800 \text{ кг/М}^3$	0,720	1,2	0,95	0,821
3	Insulation - slabs mineral wool, $\delta = 0,25 \text{ m}, \rho_m = 100 \text{ кг/М}^3$	0,250	1,3	0,95	0,185
4	Vapor barrier film	0,014	1,2	0,95	0,016
5	Cement-sand screed, $\delta = 0,02 \text{ m}, \rho_m = 1800 \text{ кг/М}^3$	0,360	1,2	0,95	0,410

6	Reinforced concrete floor slab coverage, $\delta = 0,16 \text{ m}, \rho_m = 2500 \text{ кг/м}^3$	Load is automatically taken into account by the program			
Total:		1,464			1,557
	<i>Variable load</i>				
	snow	1,240	1,14	0,95	1,414
	<i>Full load</i>	2,704			2,971

Table 3. Collection of loads from external walls

№	Load name	Characteristic load, kPa	coefficients		Design load, kPa
			$\gamma_r$	$\gamma_n$	
	<i>Permanent load</i>				
1	Lime-sand mortar, $\delta = 0,02 \text{ m}, \rho_m = 1600 \text{ кг/м}^3$	0,320	1,2	0,95	0,365
2	Lightweight concrete blocks, $\delta = 0,2 \text{ m}, \rho_m = 400 \text{ кг/м}^3$	0,800	1,2	0,95	0,912
3	Insulation – slabs mineral wool, $\delta = 0,05 \text{ m}, \rho_m = 90 \text{ кг/м}^3$	0,045	1,3	0,95	0,056
4	Brickwork made of ceramic hollow bricks on cement-sand mortar $\delta = 0,12 \text{ m}, \rho_m = 1200 \text{ кг/м}^3$	1,440	1,2	0,95	1,642
Total:		2,605			2,975

The load on 1 m of the floor slab from the wall is determined depending on the height of the floor (for example, 3 m):

- constant characteristic  $2,605 \cdot 3 = 7,815 \text{ kN/m};$
- constant design  $2,975 \cdot 3 = 8,925 \text{ kN/m}.$

### Algorithm for creating a calculation model of a building in the KLOPONOVKA program

1. Create a new task.
2. Assign general characteristics of the building.
3. Assign materials to the elements of the calculation scheme.
4. Set the grid of coordinate axes of the designed building.

5. Place vertical structural elements on the plan - columns, pylons and walls.
6. Model openings in the walls.
7. Set the contour of the floor slab. Adjust the contour by specifying new nodes. Model openings in the slab. Set the load.
8. Perform modeling of the foundation slab, set the load.
9. Review the 3D model of the building and adjust the calculation scheme.
10. Set wind and seismic effects (the latter - if necessary).
11. Set the reliability coefficients and duration of the load action.
12. Perform a calculation of a typical floor and copy floors. Make floor adjustments.
13. Perform a preliminary calculation of the entire building. Display the specified loads and the results of the floor calculation.
14. Perform a final calculation using the finite element method (FEM calculation).
15. Generate and prepare for printing a calculation explanatory note based on the FEM calculation results.
16. Export data to the MONOMAKH-SAPR PC design programs.

**List of literary sources: [1], p. 139-180; [8], p. 7-118.**

**Questions for self-control:**

1. What initial data is required to create a calculation model in the KOMPONOVKA program?
  1. Describe the main stages of building a calculation scheme.
  2. Which building calculation results are final?
  3. What commands can be used to display the results of a static calculation on the screen—displacements, stress fields, and forces?
  4. How to view information about a specific element or node of the

calculation scheme?

5. How is an explanatory note formed based on the results of a static calculation?

6. How are the calculation results exported to element design programs?

7. Give an algorithm for creating a building model by importing data from a DXF file from the AutoCAD program.

## **Topic 9. Calculation and design of a monolithic floor slab in the SLAB program in import mode from the KOMPO NOVKA program**

### **Topic content:**

Importing a file with the results of a slab calculation from the KOMPO NOVKA program. Model calculation in the SLAB program. Analysis of calculation results and reinforcement mosaics. Slab design.

### **Slab calculation algorithm**

1. Launch the SLAB program.
2. Import files created in the KOMPO NOVKA program.
3. Check the import of loads.
4. Check the data in the Materials window.
5. Slab calculation.
6. View calculation results and reinforcement mosaics.
7. Setting the reinforcement color scale.
8. Designing a slab based on reinforcement mosaics: main reinforcement, control of residual reinforcement. Preparation of slab drawing and specifications.
9. Formation of a calculation note.



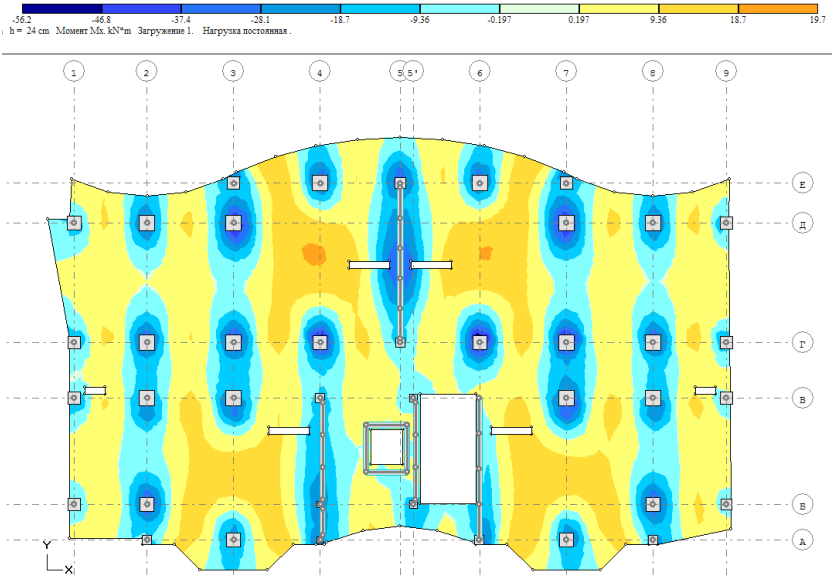


Fig. 18 – Moment isofields Mx

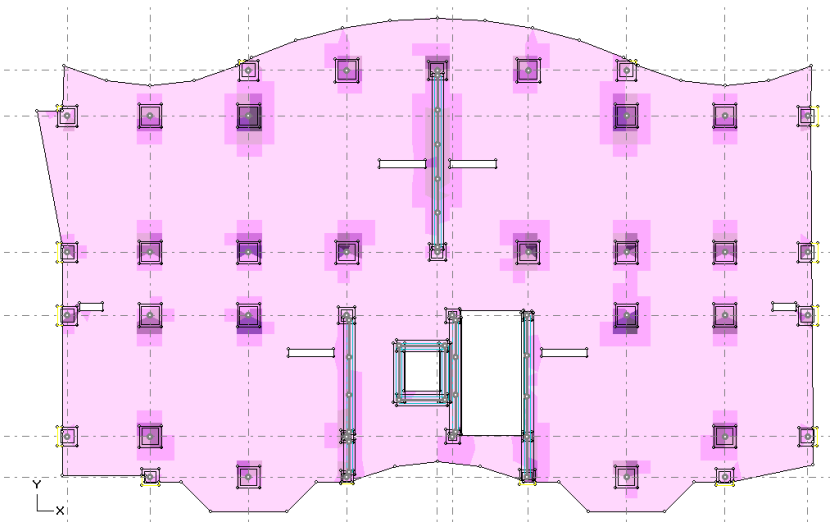


Fig. 19 – Reinforcement mosaic Ax near the upper edge of the slab

### ***Setting the reinforcement color scale***

*When setting up the color scale of the design reinforcement, you can specify ranges not only in numerical form, but also in analytical form. In this case, the value is specified as a formula. For example, the formula s200d10 means a diameter of a reinforcing bar  $d = 10$  mm with a step of  $s = 200$  mm and corresponds to a reinforcement area of  $3.925$  cm<sup>2</sup>. The formula 5d10 (or k5d10) means 5 bars with a diameter of  $d = 10$  mm per 1 linear meter and corresponds to a reinforcement area of  $3.925$  cm<sup>2</sup>. You can specify an expression of the form s200d8 + s200d22 or a mixed expression of the form s200d8 + 19.01, where 19.01 is the area value in cm<sup>2</sup>.*

If you need to change the scale parameters, open the Scale Parameters dialog box using the Results – Scale Parameters menu (button on the toolbar) and make the necessary changes. As a result, the isofields will be displayed according to the new scale parameters.

This presentation of reinforcement isofields is most often used in real design because it corresponds to the common principle of slab reinforcement: along the entire slab, near the lower and upper edges of the slab, bars of the main reinforcement are inserted, and in places where reinforcement is required, bars of additional reinforcement are inserted.

It is necessary to carefully analyze the location and dimensions of the range on the diagram that does not have a formula description and, if necessary, make corrections to the range table. For example, you can increase the diameter of the additional reinforcement layer or reduce the reinforcement pitch.

### ***Generating and reviewing a settlement note***

Create a calculation note using the menu Results – Calculation note – Save HTML file. You can also save the explanatory note as an RTF file.

## ***Slab design***

Slab design is performed using reinforcement mosaics. Mosaics help to identify slabs with the maximum calculated value of design reinforcement on the SE diagram.

For the specified layout zones, the pitch and diameter of the longitudinal reinforcement bars near the upper and lower faces of the slab are selected. Residual reinforcement control is performed. The residual reinforcement area is determined for each SE slab as the difference between the calculated value of the reinforcement area and the value of the reinforcement area provided by the meshes or bars specified in the layout sections. For a slab with a cross-sectional height of 160 mm, transverse reinforcement is not used, design with transverse reinforcement is not performed.

**List of literary sources: [1], p. 181-192; [8], p. 119-154.**

### **Questions for self-control:**

1. How to start working in the SLAB program?
2. How to import the necessary file with the results of the slab calculation from the KOMPONOVKA program?
3. How to perform the slab calculation?
4. How to view the results of the static calculation of the slab?
5. How to view the results of the selected slab reinforcement?
6. How to set the color scale of the calculated reinforcement?
7. How to create an explanatory note?
8. How to design the slab?

9. How to control the residual reinforcement?
10. How to perform the layout of the main and additional reinforcement?
11. How can I correct the drawing?

## **Topic 10. Design of columns and pylons in the COLUMN program**

### **Topic content:**

I. Creating a column (pylon) model in the COLUMN program. Calculation. Changing design parameters. Exporting data on releases. Creating a calculation note. Preparing a column drawing. Creating a list of details.

II. Importing a file with the results of the column (pylon) calculation from the KOMPO NOVKA program. Model calculation in the COLUMN program. Designing a column (pylon).

### **Column (pylon) calculation algorithm in model creation mode in the COLUMN program**

1. Launch the COLUMN program.
2. Create and save a new problem.
3. Adjust the characteristics of materials and column geometry.
4. Specify loads.
5. Column calculation.
6. Define design reinforcement.
7. Column design.
8. Change design parameters (if necessary).
9. Export release data for FOUNDATION.
10. Column drawing. Adding details.
11. Generate a design note.

## **Column (pylon) calculation algorithm in import mode from the KOMPONOVKA program**

1. Launch the COLUMN program.
2. Import files created in the KOMPONOVKA program.
3. Check data in the "Materials" window.
4. Add columns of 2-3 floors from import files.
5. Column (pylon) calculation.
6. View calculation results.
7. Generate calculation note.
8. Create a column (pylon) drawing.

**List of literary sources: [1], p. 193-199; [8], p. 186-194.**

### **Questions for self-control:**

1. What is the COLUMN program intended for?
2. List the main stages of work in the calculation scheme creation mode.
3. How to specify material characteristics?
4. How to specify geometric parameters of an element?
5. How to specify the load on a column (pylon)?
6. How to change design parameters?
7. How to export data on releases?
8. How to prepare an explanatory note?
9. How to create a column (pylon) drawing?
10. How to add a list of parts to a column (pylon) drawing?
11. List the main stages of creating a calculation scheme for a column (pylon) in the import mode from the KOMPONOVKA program.
12. How to perform data correction?

13. How to specify the design diameters of rods, the thickness of the protective concrete layer?
14. How to specify the type of transverse reinforcement?
15. How to change design parameters?
16. What command should be executed to take into account the presence of outlets in the upper column or pylon?
17. What command should be executed to design a column (pylon) with two or three floors?

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## EDUCATIONAL AND METHODOLOGICAL EDITION

- C 13     **CAD in Construction** [text]: methodological instructions for independent work for applicants of the first (bachelor's) level of higher education of the educational and professional program "Construction and Civil Engineering" in the field of knowledge 19 Architecture and Construction, specialty 192 Construction and Civil Engineering full-time and part-time forms of study / compiled by S. Rotko. Lutsk: LNTU, 2026. 44 p.

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