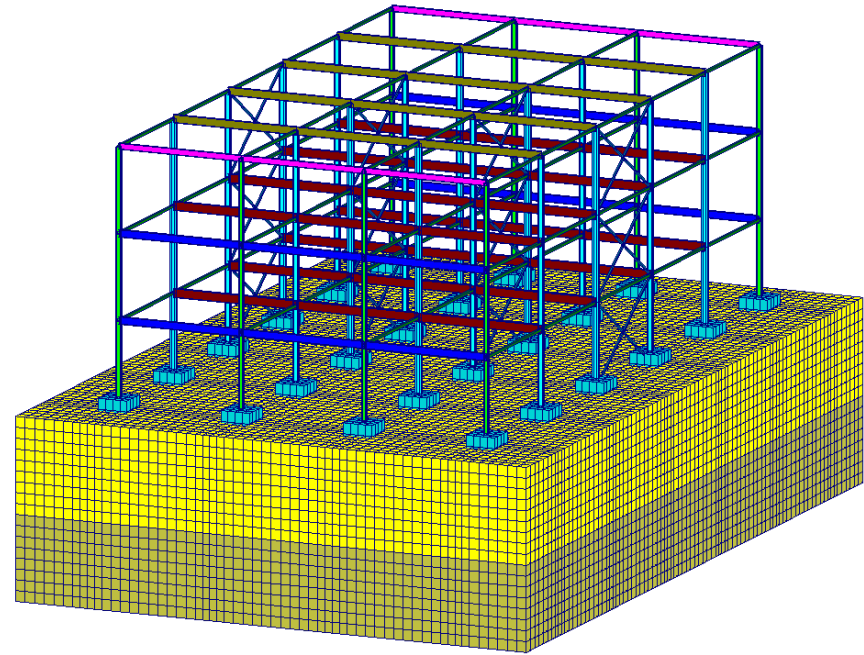
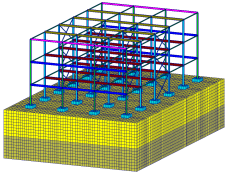


Topic 4. Analysis of the Soil-Foundation- Structure System



Types of design schemes for buildings



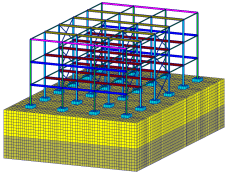
The design scheme of a building (structure) is a simplified, idealized scheme of a real structure, introduced into the calculation, which reflects its main properties and neglects secondary properties and minor details that slightly affect the operation of the structure.

The choice of a design scheme largely determines the complexity of the calculation and the correctness of the results obtained. To determine the structural scheme of the structure, it is necessary to be well versed in the principle of operation of this structure and its individual elements, the principles of interaction of the elements of the structure with each other.

All structures are spatial systems. However, often, if the structure of structures allows, spatial systems are divided into flat ones, in which case their calculation is greatly simplified. This approach can be applied if in a spatial system it is possible to distinguish flat load-bearing elements (frames, trusses), interconnected by transverse links.

In the structures of structures, there are rod elements, plates, shells and massive bodies, which are interconnected into a single system using nodal connections (or just nodes) and resting on the ground (foundation) with the help of supporting devices (supports).

Types of design schemes for buildings

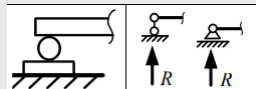


Bar elements are rectilinear or curved spatial elements in which one dimension (length) is significantly larger than the other two (transverse dimensions). In structural diagrams, such elements are replaced by their centerlines (straight, curved or broken) and are called elements. At the same time, when calculating, of course, the parameters of the cross-sections of these elements are also taken into account due to their respective characteristics (cross-sectional areas, moments of inertia, etc.), reduced to the centers of the cross-section.

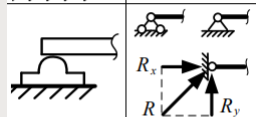
If the structure consists only of rod elements, then it is a rod system. Real support devices in structural diagrams are replaced by ideal supports (support connections).

Supports are devices that transfer loads from structures, structures to the base connected to the ground.

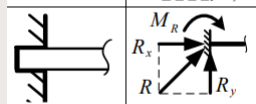
Articulated-movable



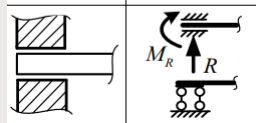
Articulated-fixed



Hard

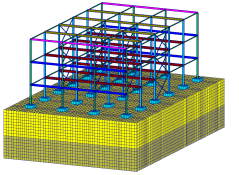


Linear Hinge



Knots can be rigid, hinged and elastic (pliable). A hinge joint (or simply a hinge) is considered as a device that allows mutual rotation of the connected elements relative to the center of the hinge. On the design diagrams, the hinge is indicated by a circle. Frictional forces in the hinges are usually neglected. A rigid connection of elements (rigid assembly) completely excludes their mutual displacement, and the angle between the axes of the rods in it does not change when the system is deformed.

Types of design schemes for buildings



The division of nodes into perfectly hinged and perfectly rigid is not always true. Often the nodes are malleable and allow mutual movements of the connected elements (turns, shifts) depending on the internal forces arising in the node.

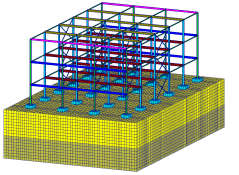
In real structures, any elements (racks, beams, slabs, shells, etc.) always have some deviations from the structural shapes, sizes, properties of the materials used, which arise during their manufacture, transportation, assembly and which are most often not taken into account in structural diagrams. It is impossible to imagine a perfectly straight pole, which looks like a straight rod on the design diagrams. Hinged joints of elements (hinges) are considered ideal, that is, it is believed that there are no frictional forces in them, and forces are transmitted through the centers of the hinges, which is difficult to achieve in practice.

The choice of a design scheme is the first very important and difficult part of this calculation – the design scheme must be selected in such a way as to take into account all the main features of this structure and at the same time facilitate the calculation as much as possible.

The degree of accuracy of displaying the real operation of the structure according to the design scheme is associated with the possibilities of taking into account in the design scheme:

- actual geometry of structural elements and their connections;
- various physical and mechanical properties of structural materials;
- influences and loads that actually act on the structure;
- the use of calculation methods, computer programs and computer equipment that allow you to perform the calculation with the required accuracy.

Types of design schemes for buildings



The classification of structures and their structural schemes can be carried out according to various criteria.

All structures are spatial. However, as already noted, they can and often are calculated as flat systems.

According to geometric features, there are:

1. Rod structures (consisting of rods - beams, trusses, frames).
2. Structures made of slabs and shells.
3. Massive structures (retaining walls, dams).
4. Combined systems, which are a combination of systems 1-3.

According to the features of the operation of structures, there are:

1. Beam structures.
2. Arched structures.
3. Frames are rod systems with a rigid connection of elements in all or several nodes.
4. Trusses are systems, all elements of which experience almost only stretch-compression.
5. Suspension systems – in which the main, mostly flexible elements work only in tension.
6. Plates.
7. Shells.
8. Structures are modeled with three-dimensional elements.
9. Combined systems, which are a combination of systems 1-8.

Types of design schemes for buildings

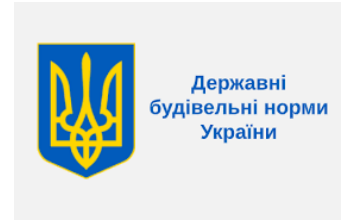


Calculations of foundations of the system "foundation - foundation - structure" by deformations, including in difficult engineering and geological conditions, should be performed using a linear or nonlinear relationship "stress (pressure) - deformation (subsidence)", taking into account the factors that determine the stress-strain state of the foundation and structures of the structure and the properties of the base soils.

The design scheme of structures: with significant consequences (CC3) - in all cases, with medium consequences (CC2) - in difficult engineering and geological conditions and with heterogeneous compressibility of the base should take into account the spatial work of structures. It is necessary to take into account physical and geometric nonlinearity, anisotropic and rheological properties of soil deformation of soil and structural materials, the sequence of construction of structures, the level of loads and the increase in rigidity of the structure during the construction process.

When calculating foundations, seismic and man-made dynamic influences (working technological equipment, traffic, pile driving) should be taken into account.

Types of design schemes for buildings



To calculate the interaction of the structure, foundation and foundation, a spatial calculation model should be formed in compliance with the following provisions:

the calculation model must ensure the operation of the system and its analysis in design situations;

for the joint calculation of the structure with the base, analytical, numerical and other methods can be used; the design scheme should be chosen taking into account the most significant factors that determine the stress-strain state of the foundation and structures of the structure;

the model should be built on the basis of the parameters of the structural solutions of the ground, foundation-basement parts of the structure and the soil base, as well as the possibility of their changes in the process of construction and operation;

the degree of sampling of the base model should provide the ability to model the boundaries of layers and lenses with different soil properties and set the parameters of special influences;

the calculation model of the base should reflect the lithological structure of the site, the properties of the selected engineering and geological elements, the location of the RGV, if necessary, the presence of excavations, zones of local watering;

characteristics of materials should be assigned taking into account the nonlinear nature of deformation (for example, the use of criteria for assessing the transition of soil to a plastic state, models of viscoelastic deformation);

the calculation model should provide for the possibility of excluding stretched connections between the foundation and the soil massif;

sections of the design model in which the forces exceed the strength of materials should be simulated by reducing the values of the corresponding stiffeners or excluding them from the calculation of the corresponding finite elements; - geometric characteristics of sections of structural elements, including foundation, should be assigned taking into account tolerances (minimum values) and/or accept the characteristics of sections with defects.

Types of design schemes for buildings



Державні
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It is recommended to present the design model of the "foundation - foundation - structure" system in the form of spatial substructures - the main models of subsystems: the base, foundation and the super-foundation part of the structure. When combining subsystems into a complete system "foundation - foundation - structure", it is necessary that at their boundaries the conditions of compatibility of movements of the base and foundation, foundation and supra-foundation part of the structure and the conditions of balance of forces (stresses) acting on the foundation and foundation, on the foundation and structure are met.

Checking the overall stability of the soil mass together with the structure (foundation) should be carried out if:

The structure (foundation) is located:

- a) on a natural slope, artificial slope or near them;
- b) near an excavation or pit of an existing structure;
- c) near a mine working, underground structure or natural cavities (in particular, karst, sufosis);

The base is made up of steeply inclined layers of soil.

Loading and calculation of structural elements



Державні
будівельні норми
України

Even more approximations are associated with loads, the exact values of which in some cases are almost impossible to determine. The standard values of snow and wind loads are calculated on the basis of statistical processing of load values based on the results of long-term observations. The distribution of loads into concentrated forces and moments, into evenly distributed loads is also rather arbitrary.

All impacts on structures can be divided into power (load), temperature and kinematic (displacement of supports and connections).

In this case, the effects can be static and dynamic.

Static effects include shocks and loads that increase from zero to the final value so slowly that the velocities and acceleration of the points of the systems when they are deformed are small and the forces of inertia can be neglected.

Dynamic influences include those that give the masses of the structure significant accelerations and, accordingly, cause such inertial forces that their influence must be taken into account.

Examples of dynamic effects are shock and vibration loads, blast wave effects, and seismic effects.

Force effects or loads are represented by concentrated forces, concentrated moments, distributed loads of constant or variable intensity. These loads can be mobile and stationary. Constant loads act constantly in one place. Movable ones move through the system (for example, transport on a bridge, a crane on crane beams, etc.).

Creation of the calculation scheme "foundation-foundation of the structure"



Imprint:

The initial data for the calculation are the parameters of the object, which characterize:

influences of the operating environment;

properties of materials and soils;

dimensions, position in space, conditions for fixing structures and their elements.

Norms for the design of structures for various purposes should also take into account the possible dependence of the initial data on environmental conditions.

Mechanical influences taken into account in the calculation directly are considered as a set of forces applied to the structure (load), or as forced movements and deformations of structural elements. Other influences of a non-mechanical nature (for example, the effects of an aggressive environment) are taken into account in the calculation indirectly.

Depending on the cause of occurrence, influences are divided into:

the main ones, which are the inevitable consequences of natural phenomena or human activity;

emergency, which are undesirable results of the human factor, or the results of an unfavorable coincidence of circumstances of a man-made nature. Depending on the time variability, influences are divided into:

constant, which operate during the entire period of operation of the object and the values of which do not change significantly in time;

variables for which the change in values over time with respect to the mean cannot be neglected (long and short-term).

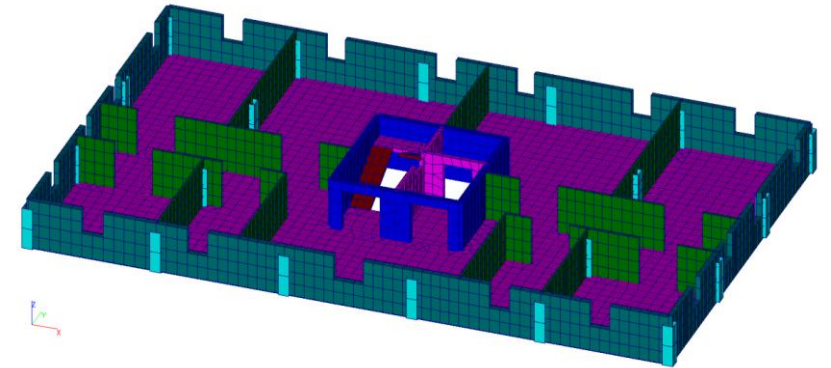
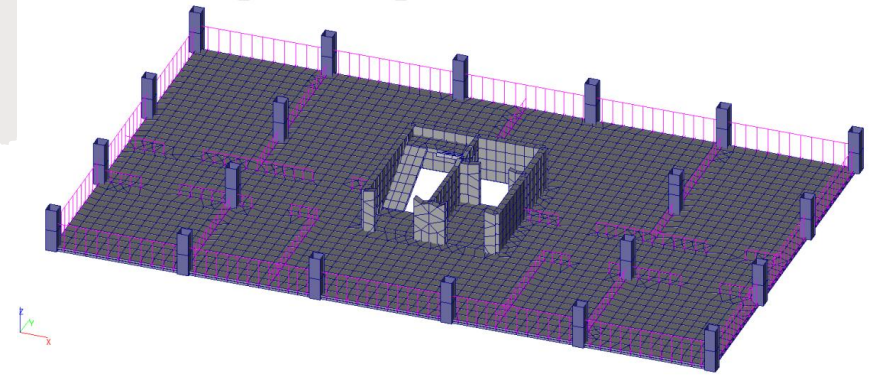
Creation of the calculation scheme "foundation-foundation of the structure"

The construction of a computational model begins with establishing which parameters are essential and which can be neglected. The need for such simplification is due to the fact that the creation of a model and the execution of the calculation, taking into account all the properties of a real structure, is possible only with a certain degree of approximation.

The structure of the building is freed from insignificant features (Pareto's principle) and presented in a certain simplified (idealized) form, called a design scheme.

Simplification methods include: idealization of the material to a continuous and homogeneous medium, bringing geometry to standard elements (rods, shells, plates or their approximate approximation by volumetric elements), schematization of external forces and influences, replacement of non-basic structures with schematic loads from them, etc.

The choice of the design scheme is the most important stage of the analysis and characterizes the level of professionalism of the engineer.



An example of a model of a typical building floor with varying degrees of detail

Creation of the calculation scheme "foundation-foundation of the structure"

At the first stage, it is necessary to decide how the calculation will be performed: as linear or as non-linear, whether it will be necessary to perform a dynamic calculation (and, accordingly, take into account the forces of inertia), or it is possible to limit yourself to static analysis (in accordance with the requirements of state building codes).

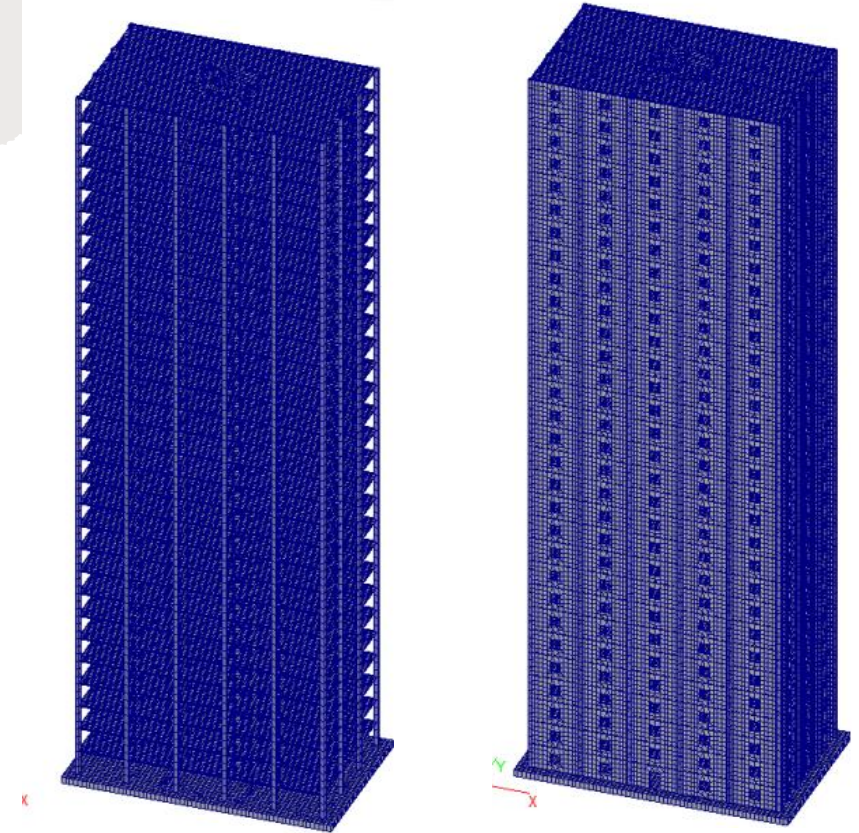
Features of the structural scheme of the building, its behavior under loads and their type, the type of calculation adopted affects the choice of the design scheme, for example, the assignment of boundary conditions, the level of detailing, the schematization of loads, etc.

Especially serious is the issue of splitting the system into finite elements, that is, into standard parts that should make up the entire model.

Too fine fragmentation leads to an increase in calculation time and an increase in the request for computer resources.

Too coarse crushing can lead to a decrease/loss of accuracy of results (especially in plate and volumetric elements).

There are no general recommendations for choosing the optimal level of crushing, except for the iteration of calculation systems with varying degrees of crushing of certain fragments.



An example of a model of a typical building floor with varying degrees of detail

Loading and calculation of structural elements



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Loads and impacts:

Depending on the method of applying loads in space, they can be:

fixed, which can only act on well-defined places of construction;

free, which can be arbitrarily distributed over the structure within some specified limits.

Taking into account free loads can be reduced to considering a number of complexes of fixed loads obtained by fixing the possible distribution of free loads in space.

Depending on the reaction, structures are divided into:

- static, which do not cause significant accelerations of the structure, which allows you to neglect inertial forces;
- dynamic, which cause such accelerations that inertial forces cannot be neglected.

The load can be represented by the sum of two components: static and dynamic. To simplify the calculation, in some cases specified in the design standards, the dynamic effect can be considered as static, and the dynamic effect, depending on the reaction of the structure, can be taken into account by increasing the load accordingly or multiplying the results of the static calculation by the coefficient of dynamism.

Loading and calculation of structural elements



Державні
будівельні норми
України

Loads and impacts:

The strength and deformability characteristics of materials and soils are determined by statistical processing of data obtained by testing standard samples and are reduced to the characteristics of real materials in real structures using transient coefficients or functions, as well as corrections for the level of work performed and the expected control system.

To determine the physical and mechanical characteristics of soils, the results of tests in field and laboratory conditions are used, taking into account possible changes in soil moisture during the construction and operation of the facility.

To normalize the characteristics of strength and deformability of materials and soils, it is allowed to use the results of determining other physical characteristics (for example, strength under other types of deformation, hardness, elasticity, magnetic properties), if, as a result of preliminary research, reliable dependencies between the measured parameters and the required strength (deformability) characteristics have been established.

Geometric characteristics that determine the dimensions, shape and position of structures and their elements should be considered as accidental if their deviations from the values established by the project significantly affect the reliability of structures. The characteristics of their variability should be determined taking into account the established tolerances for the manufacture and installation of products and structures.

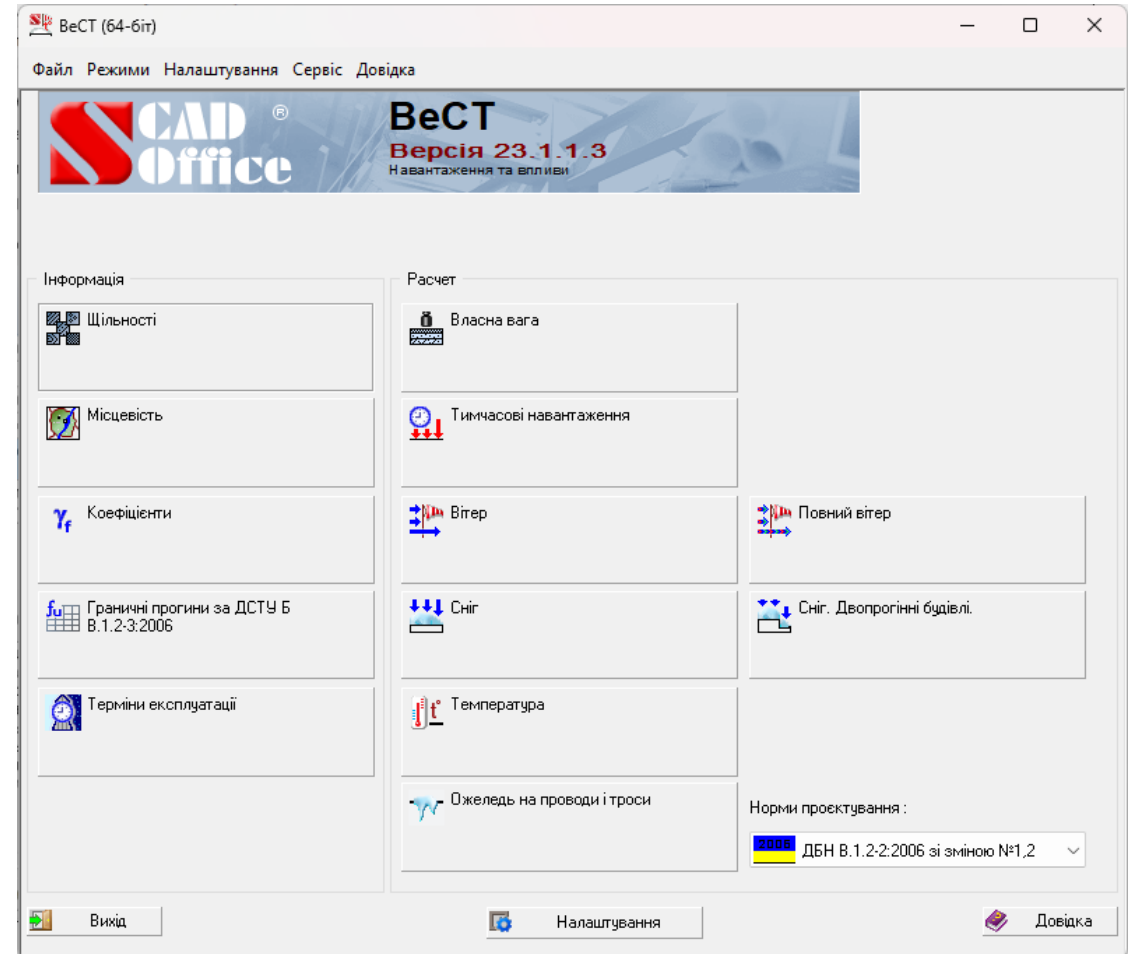
If the influence of variability of geometric characteristics on the reliability of structures is much less compared to the influence of variability of loads and technical characteristics (physical and mechanical properties) of materials. In such cases, geometric characteristics are considered as deterministic quantities with nominal values specified in the design documentation.

Determination of standard loads

VesST Program

The VeST program is designed to perform calculations related to the determination of loads and actions on DBN of Ukraine V.1.2-2:2006 "Loads and Impacts", taking into account amendments No. 1, 2 of June 1, 2020. The program implements only load cases that occur most often, as well as those cases for which the fulfillment of the requirements of regulatory documents is associated with a rather complex logic and which, as experience proves, most often lead to errors.

In addition to this function, the VeST to some extent plays the role of a reference book, with the help of which it is possible to clarify some actual data on the zoning of the territory by loads and actions or to obtain other specific data of a reference nature.



VesST Program

The information and reference section of the program contains the following modes:

Densities — contains data on the densities of basic building materials;

Terrain is used to determine load parameters that depend on the geographical location of the construction site;

Coefficients are reference data on the value of the reliability coefficient by load γ_f ;

Marginal deflections — reference data on normalized values of marginal deflections and displacements;

Service life (according to DBN) — reference data on the service life of buildings and engineering structures;

Vehicle loads are reference data on vertical loads from vehicles.

Design modes are represented by the following set:

Dead weight — the mode makes it possible to determine the value of the load from the dead weight of a multilayer package made of different materials, which falls on a unit of area;

Temporary loads — the values of evenly distributed temporary loads (full and reduced values) are set in different rooms according to the instructions of the DBN;

Wind — mode is designed to calculate the static component of wind loads for structures of various types;

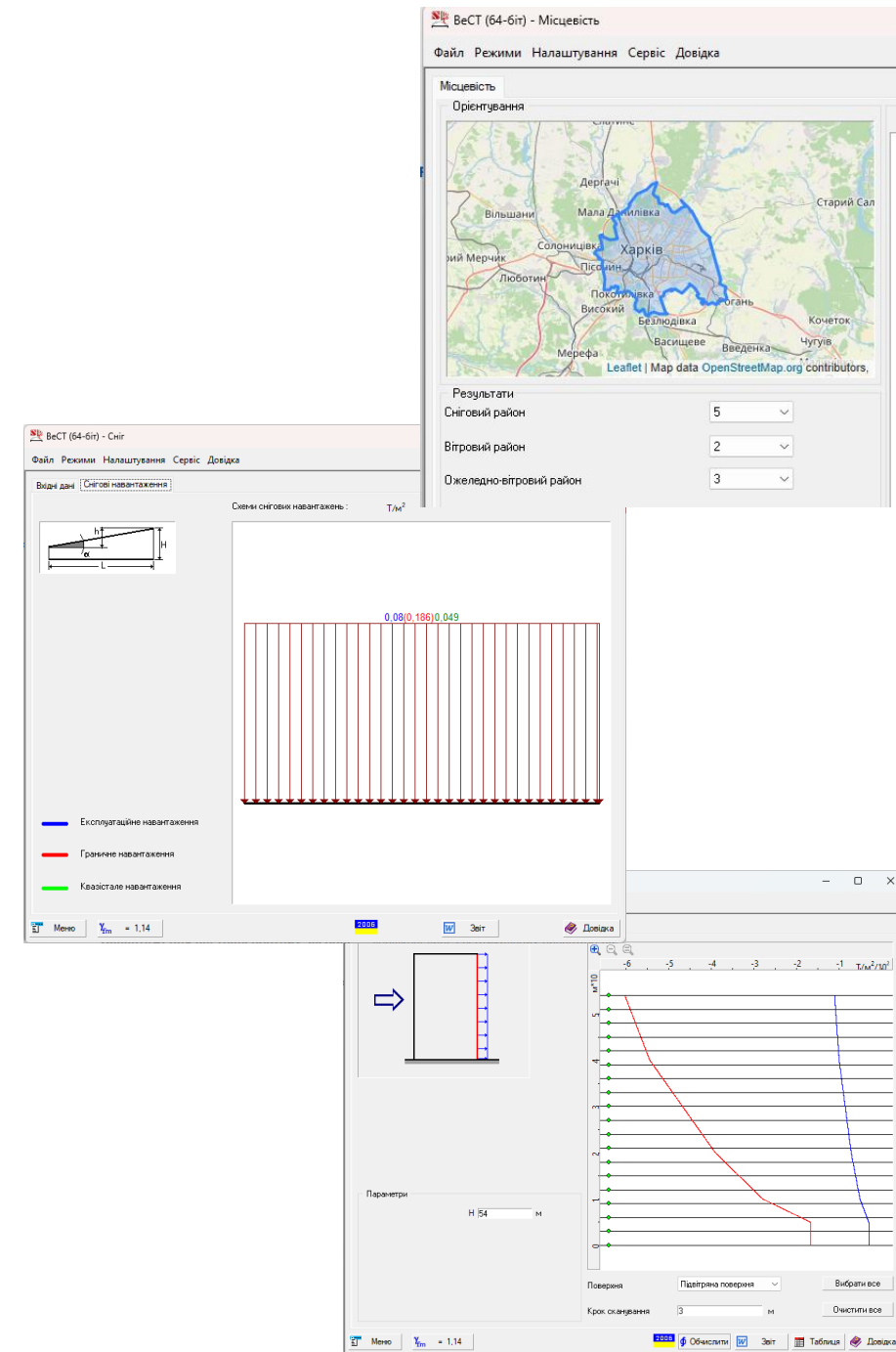
Full wind — calculation of wind loads taking into account the dynamic action of the pulsation component for vertical prismatic and cylindrical structures according to DBN;

Snow is a mode designed to calculate snow loads for structures of various types from among those provided for by design standards;

Snow. Two-span buildings — calculation of snow loads for two-span buildings of various types from among those provided for by design standards;

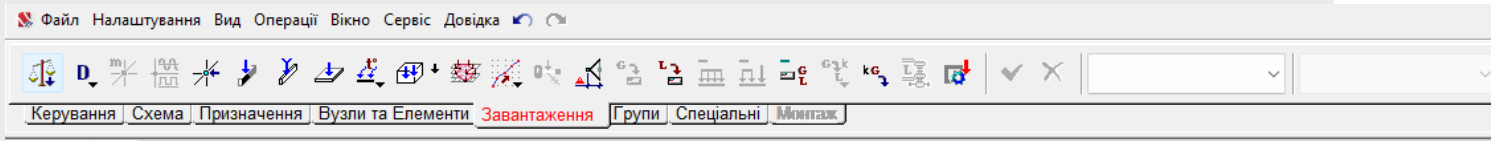
Temperature — the mode is designed to set the temperature of actions;

Ice on wires and cables is the calculation of loads from the weight of ice and from the action of wind on wires and cables covered with ice deposits.



Loading and calculation of structural elements

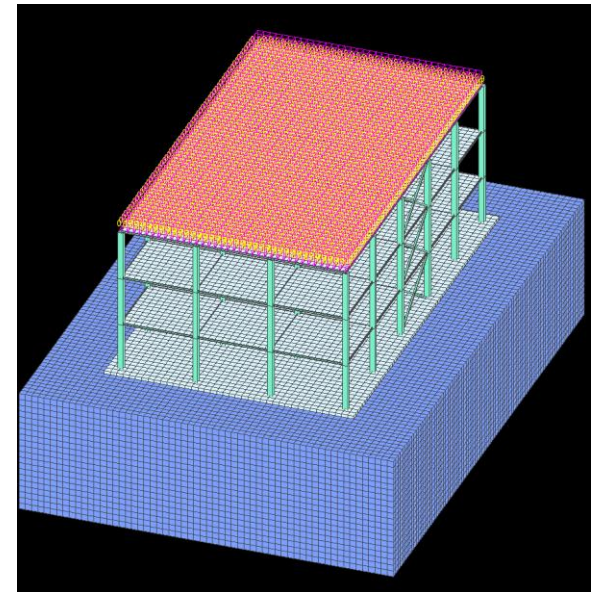
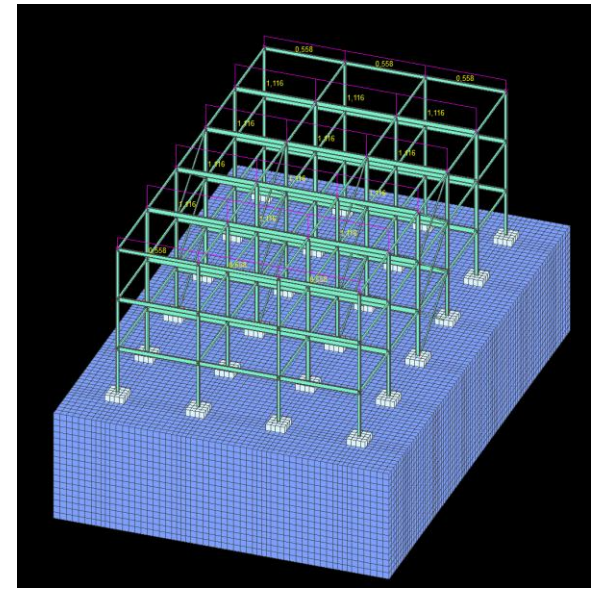
The management of load diagram creation operations is concentrated in the "Loading" section of the dashboard.



The loads acting on the calculated structure are determined in the form of nodal forces and moments, as well as concentrated, trapezoidal and distributed forces and moments on the elements.

Loads can include a set of loads of any kind and are characterized by a number and name. If some load sets occur in more than one load case, load groups can be created during the load generation process that include these load sets.

Groups are stored under the specified names and can be added in any download cases.

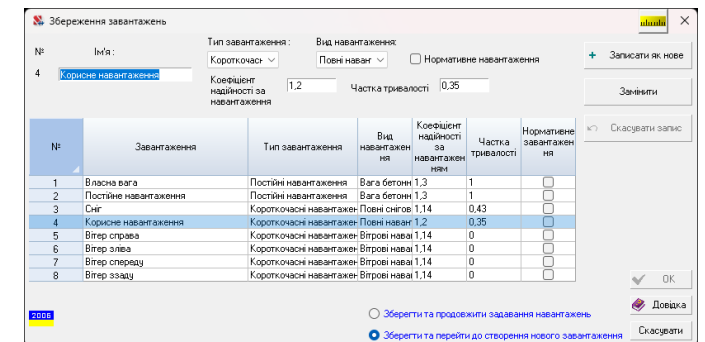
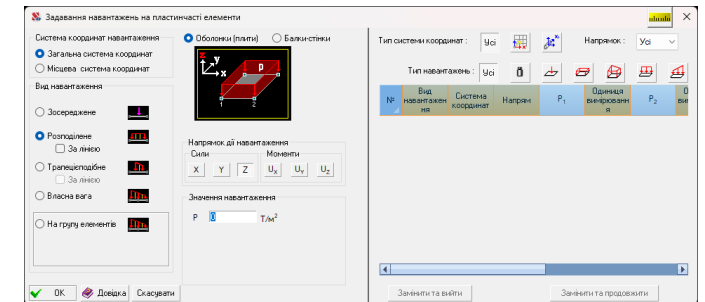
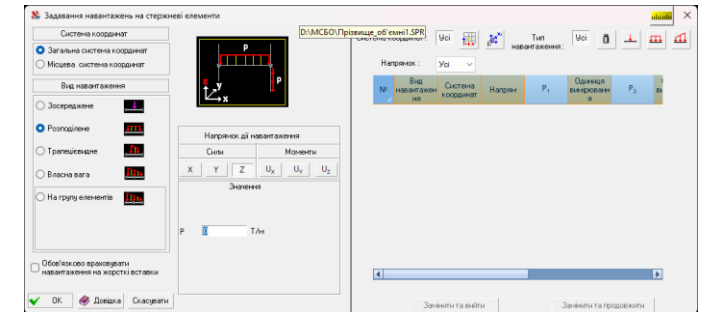
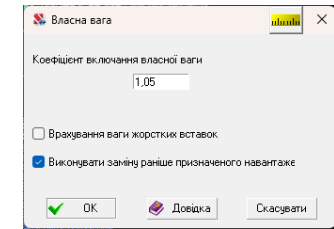


Приклад розрахункової моделі з різним рівнем деталізації та схематизації навантажень (на прикладі снігового навантаження)

Setting static loads

When setting static loads, the following procedure is recommended:

- use the buttons of the dashboard to select the type of load (nodal or elemental);
 - In the dialog box with load parameters, specify the type, direction and value of the load;
 - select the nodes or elements to which the specified load is attached;
 - press the OK button in the "Downloads" section of the toolbar or press the Enter key on your keyboard.
 - repeat the described operations for other loads included in the current load;
 - after assigning all loads to the current load, click the Save/Add Load button;
 - In the Save Downloads dialog box, enter a name for the download, specify its characteristics, and click OK.
 - Before entering a new (next) load, click the "Remove all charges" button on the toolbar.
- The "Save/Add Load" operation should complete the load setting of the current load. Otherwise, the input loads will not be taken into account in the calculation. The load characteristics defined in the Save Loads dialog box are automatically taken into account when generating the calculated force combinations (DCS). It is recommended to give loads unique names that characterize the purpose of loads. The "Clear all loads" operation clears the temporary (buffer) memory in which the loads of the current load accumulate, and allows you to prepare a record of a new load. Obviously, this operation must be performed after the download has been saved.



Automatic Self-Weight Assignment



The operation is performed for rods, plates and volumetric elements - and only if the volumetric weight of the material is assigned in the stiffness characteristics of the elements.

The dead weight of the elements per unit length/area is calculated as the product of the cross-sectional area of the elements or the thickness of the insert and the volumetric weight of the material. For stiffness, when using a numerical or numerical-parametric description of stiffness, SCAD works according to the following algorithm: the value of EF is taken from the numerical description, divided by Young's modulus E (we get an analogue of the cross-sectional area) and multiplied by the specific gravity of the material.

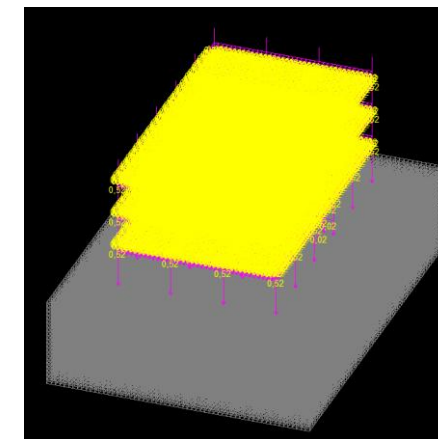
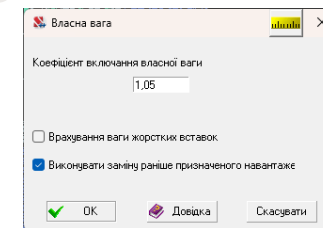
After activating the operation, the Own Weight dialog box appears, in which you can specify the coefficient for including your own weight, as well as the rules for assigning loads:

- assign loads to all elements or only those indicated on the diagram, which allows you to set different coefficients for different groups of elements;
- to include or not to include rigid inserts in the length of the element, i.e. to take into account the "weight" of rigid inserts;
- to replace the own weight inclusion factor when the operation is switched on again or to sum up the new value of the coefficient with the previous one.

If the operation detects items that cannot be assigned a dead weight load, a message box appears with a list of such items.

Dead weight loads are modeled as distributed forces acting on the elements in the direction of the Z-axis of the general coordinate system.

To display the distributed loads on the diagram, the corresponding filter button is used. When you press the filter button, the load intensity value is also displayed next to the image.



Nodal loads



Nodal loads are defined in the Nodal Load Input dialog box, which appears when you click the corresponding button in the Loads section of the toolbar.

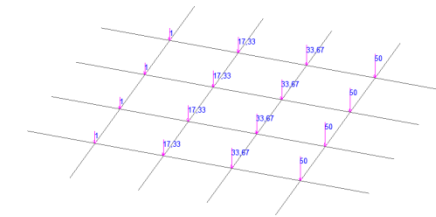
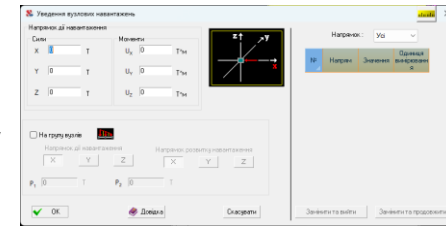
If nodes within the same load are loaded in different directions, then such a set of loads can be set immediately. In this case, the icon displaying the positive direction of the corresponding load will show the direction of the load, in the input field of which the cursor is located.

The following procedure for the introduction of nodal loads is recommended:

- activate the Nodal Loads operation;
- in the dialog box of the same name, set the load values that act on one node at a time;
- exit the dialog box by clicking the OK button;
- select on the diagram the nodes on which a given set of loads acts;
- press the OK button on the toolbar or press the Enter key on the keyboard.

The table in the Node Load Input dialog box displays the characteristics of all node loads that were previously defined in the current load. This data can be used to introduce new loads or adjust previously introduced loads. To select loads by direction of action, the Direction list is used (by default, all loads are displayed).

If, when selecting nodes with one cursor, several nodes hit the target, then a list of nodes in the cursor target dialog box is displayed. The node selected in the list of this window in the diagram is indicated in red, and its coordinates are displayed in the corresponding fields of the dialog box. The desired node is fixed with the Select button, after which the window closes and this node can be used to assign a load.



Rod load



The type, direction, and magnitude of the loads on the rod elements are assigned in the "Set Loads on Rod" dialog box, which appears after clicking the corresponding button on the toolbar of the "Loads" section.

The program provides for the following types of loads:

- concentrated load;
- distributed load on a part of the element;
- evenly distributed load on the entire element;
- own weight.

All types of loads can be defined both in the general and local coordinate system of the element. In addition, a load of the "hydrostatic" type can be set to a group of elements. The following procedure for introducing loads on the rods is recommended:

- activate the operation "Load on the rods";
- in the dialog box "Setting loads on bar elements" assign a coordinate system, type, direction, magnitude and, if necessary, load binding (after selecting the type of load, an icon is displayed in the window showing the positive direction of its action).
- exit the dialog box by clicking the OK button;
- select on the diagram the elements on which the specified load acts;
- press the OK button on the toolbar or press the Enter key on the keyboard.

In the item "Be sure to take into account the load on rigid inserts", you can specify a special type of load that does not fall under the calculation parameter "Do not take into account evenly distributed loads on rigid inserts of rod elements".

The table of the dialog box displays the characteristics of all component loads previously defined in the current load. This data can be used to introduce new loads or adjust previously introduced loads. To select loads by type, direction of action and coordinate system, a set of marker buttons with the type of loads is used, as well as the Direction drop-down list (by default, all loads in all directions, including dead weight loads, are displayed).

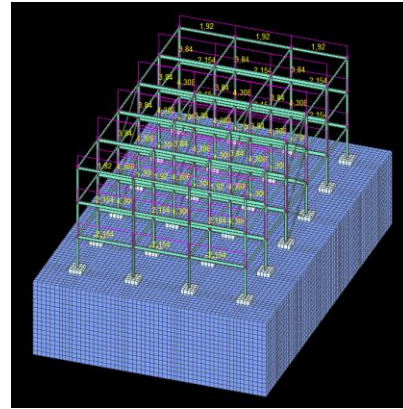
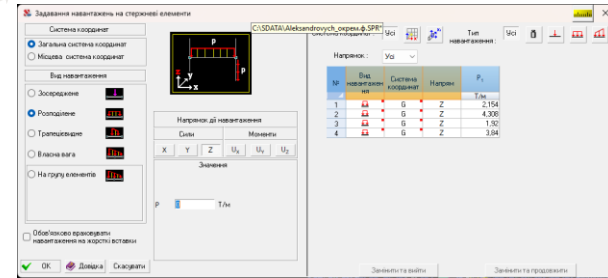


Plate loads



The type, direction and magnitude of loads on plate elements (shells, plates, beams) are assigned in the Specify Plate Element Loads dialog box, which appears after clicking the corresponding button in the toolbar of the loading section.

The program provides for the following types of loads:

- concentrated load;
- evenly distributed load on the element;
- evenly distributed load between two nodes of the element (load along the line);
- trapezoidal load on the element;
- trapezoidal load between two nodes of the element (line load);
- own weight.

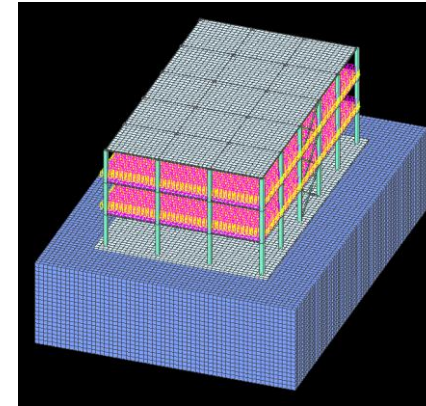
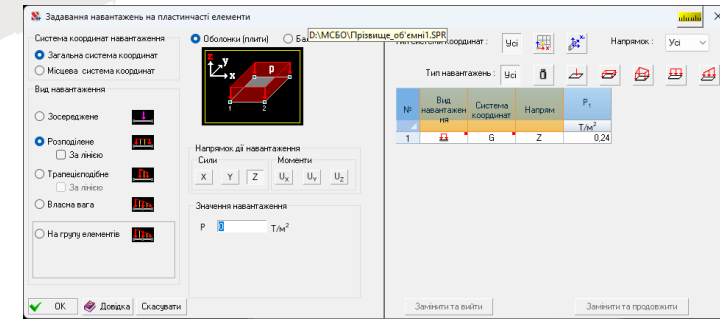
All types of loads can be defined in both general and local coordinate systems. In addition, a load of the "hydrostatic" type can be set on a group of elements.

The following order of insertion loads is recommended:

- activate the operation of the Plate Load;
- In the dialog box "Setting loads on plate elements", assign a coordinate system, type, direction, magnitude and, if necessary, load binding (after selecting the type of load, an icon is displayed in the window showing the positive direction of its action);
- exit the dialog box by clicking the OK button;
- select on the diagram the elements on which the specified load acts;
- press the OK button on the toolbar or press the Enter key on the keyboard.

An icon appears in the dialog box showing the positive direction of the load. Since the system for describing local axes differs from the system of plates and shells, when specifying loads on wall beams in the local coordinate system, it is desirable to set the button for controlling the output of icons to the Beam-wall mode.

When entering concentrated loads, the load binding within the element is checked and if the load does not fall on the element, a message is displayed with a list of elements to which the load is not assigned. In this case, this message is duplicated in the list of operations performed at the bottom of the window.



Load on volumetric elements



The program provides for the installation of the following types of loads on volumetric elements:

- load from your own weight;
- evenly distributed load over the volume of the element;
- evenly distributed load on the edges of the element;
- concentrated load.

The type of load is selected in the drop-down menu that appears after clicking on the "right arrow". The exception is the load of the dead weight, which is given, as for other types of finite elements, by the activation of the operation . To set a uniformly distributed load for any type of element, you must perform the following steps:

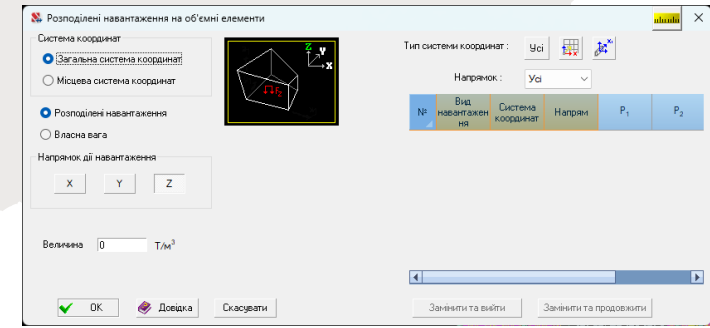


- activate the operation by pressing the Load on volumetric elements button (the right arrow is not used for this type of load);
- in the dialog box "Distributed loads on volumetric elements" that appears, select the coordinate system in which the loads and the direction of their action will act;
- set the load value;
- exit the dialog box by clicking the OK button and select the elements to which the load is assigned in the diagram.
- click the OK button on the toolbar.

To set loads on the faces of elements, the following rules are recommended if the faces are assigned by their number:

- activate the operation by clicking on the "right arrow" and selecting the section of the drop-down menu corresponding to the type of elements;
- in the dialog box "Loads are evenly distributed along the edges of the elements" select the coordinate system in which the loads will act and the direction of their action;
- set the load value;
- select from the list the number of faces on which loads will be set;
- exit the dialog box by clicking the OK button and select the items to be loaded on the diagram.
- Click the OK button on the toolbar.

Since the numbering of the faces is tied to the local coordinate system of each element, a situation may arise in which it will not be possible to set the load for all the necessary elements at once, because their local axes do not coincide in direction, which means that the faces of the same name do not coincide in position on the diagram. In this case, you can use the load assignment operation, which provides the ability to select faces not by number, but by (selected) nodes belonging to the face. This operation is called from the section "Load on the faces of marked volumetric elements".

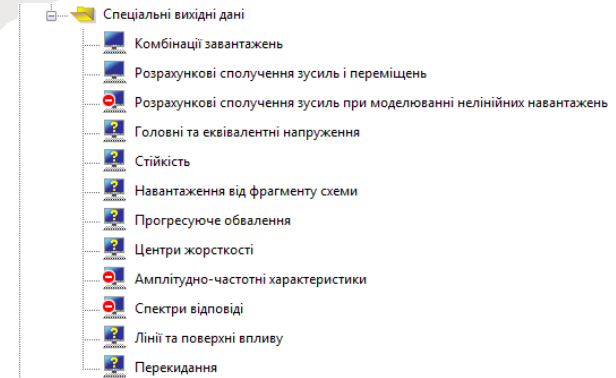


Design combinations of loads (DCL)

Determination of design combinations means finding those combinations of individual loads that can be decisive (most dangerous) for each element to be tested, each cross-section of the element for the rods and each unit.

SCAD provides definitions for the following design combinations:

- calculated combinations of forces (DCS);
- design combinations of progressive collapse;
- calculated deflection combinations (RSP);
- design combinations of movements;
- calculated combinations of reactions in knitting (PCP);
- design punching connections.



Using the principle of superposition, disadvantageous combinations of forces are selected that create maximum elastic stresses at characteristic points or in characteristic areas of finite elements. At the same time, for finite elements of different types (rods, plates, etc.), a different approach is used to assign criteria for the selection of DCS. Similarly, the maximum movements of the nodes are selected.

Linearity also assumes that some load will either enter the DCF completely or be discarded (if it creates an offload effect), and thus only $2n$ combinations (where n is the number of loading cases) can be represented from which to choose. It is easy to see that with real values of the parameter n , the number of possible combinations becomes so large that the solution of the problem by direct enumeration of options turns out to be unrealistic, and therefore a special algorithm is used to solve this extreme problem.

The program determines the combinations of both the design and normative DCS. For the found combinations of calculated values that are disadvantageous (according to one criterion or another), long-term (as well as normative and normative long-term) values of the corresponding forces, stresses and displacements are calculated. The program also looks for unfavorable combinations of standard values and calculates the calculated, calculated long and standard long values of the corresponding forces, stresses and displacements, etc.

Design norms regulate the limitation of standard displacement values, therefore, only standard and standard long-term combinations of displacements are calculated for each node.

The norms for the calculation of concrete and reinforced concrete structures require a punching analysis for flat reinforced concrete elements (slabs). SCAD allows you to calculate unprofitable (in terms of punching) load combinations. Calculations are performed in the nodes of horizontal plate elements, to which vertical rods are adjoined.

Design load combinations (DCL)

Depending on the duration of the loads acting on the designed object, the loads can belong to one of the following types (according to the DBN classification):

Permanent

Long

Brief

Special (episodic)

To simplify the algorithm for choosing combinations, the list of species has been expanded. Crane loads are added to it (although in the norms they refer to short-term loads) and inactive, that is, they do not participate in the selection of unfavorable combinations.

Constant loads include: a) the weight of parts of structures, including the weight of load-bearing and enclosing structures; b) weight and pressure of soils (embankments, backfills), mining pressure. The forces from the prestress, stored in the structure or in the base, should be taken into account in the calculations as the force from constant loads.

Variable long-term loads include: a) the weight of temporary partitions, gravity and concrete for equipment; b) the weight of stationary equipment: machines, apparatus, motors, tanks, pipelines with fittings, supporting parts and insulation, belt conveyors, permanent lifting machines with their ropes and guides, as well as the weight of liquid and solid substances filling the equipment; c) pressure of gases, liquids and bulk bodies in tanks and pipelines, overpressure and rarefaction of air that occurs during ventilation of mines; d) load on floors from stored materials and racking equipment in warehouses, refrigerators, granaries, book depositories, archives and similar premises; e) temperature technological influences from stationary equipment; f) the weight of the water layer on water-filled flat surfaces; g) the weight of industrial dust deposits, if its accumulation is not excluded by appropriate measures; h) loads from people, livestock, equipment on the floors of residential, public and agricultural buildings with quasi-constant design values; i) vertical loads from overhead and overhead cranes with quasi-constant design values; j) snow loads with quasi-constant design values; k) temperature climatic influences with quasi-constant calculated values; l) influences caused by deformations of the base, which are not accompanied by a radical change in the structure of the soil; m) influences caused by changes in humidity, components of an aggressive environment, shrinkage and creep of materials.

Design load combinations (DCL)

Variable short-term loads should include: a) loads from equipment that occur in start-up, transient and test modes, as well as during its rearrangement or replacement with limit or operational design values; b) the weight of people, repair materials in the areas of maintenance and repair of equipment with limit or operational design values; c) loads from people, livestock, equipment on the floors of residential, public and agricultural buildings with limit or operational design values, except for the loads specified in 4.12 a, b, c, d; d) loads from mobile lifting and transport equipment (loaders, electric cars, stacker cranes, hoists), as well as from overhead and overhead cranes with limit or operational design values; e) snow loads with limit or operational design values; f) temperature climatic influences with limit or operational design values; g) wind loads with limit or operational design values; h) ice loads with limit or operational design values.

Episodic (special) loads include: a) seismic effects; b) explosive effects; c) loads caused by sharp disturbances in the technological process, temporary malfunction or destruction of equipment; d) influences caused by deformations of the base, which are accompanied by a radical change in the structure of the soil (when soaking subsidence soils) or its subsidence in the areas of mine workings and in karst areas. Characteristic and calculated values of episodic loads are determined by special regulatory documents.

Load pairing

Load combinations are formed as a set of their design values or their corresponding forces and/or displacements, which is used to check the structure or base in a certain limit state and in a certain design situation. It is assumed that all loads in the selected combination simultaneously affect the calculation object.

The coupling should include the loads that most adversely affect the structures (bases) in terms of the limit state under consideration. Influences that are mutually exclusive cannot be included in the same combination.

In the calculations of structures, two types of connections can be used - main and emergency. To check the limit states of the first group, the main combinations are used, which include constant loads with limit design values, limit designed, cyclic or quasi-constant values of variable loads. To check the boundary states of the second group, the main connections are used, which include constant loads with operational design values, as well as operational calculated, cyclic or quasi-constant values of variable loads. Except for the cases stipulated in DBN B.1.1-12 and DBN B.1.1-45, in addition to constant and variable loads, only one episodic impact may be included in the emergency communication. In some cases, the verification of the emergency design situation can be performed on the action of the main combination of influences, but taking into account the impact of destructive processes or damages caused by this design situation (for example, a decrease in the bearing capacity of the structure due to fire or failure of some elements during an explosion). Requirements for the use of emergency loads and impacts are adopted according to the design standards of buildings and structures of a certain functional purpose.

Design load combinations (DCL)

The calculation is carried out on the basis of the design standards chosen by the user. You can change the norms using the Configure Design Norms item in the Settings menu.

The calculated combinations of loads are determined for each element separately (and for each section of the element), and the found set of combinations may not coincide for different elements. Thus, for the system as a whole, we get combinations of load cases that do not physically act simultaneously, so it is not possible to build an "DCF plot" or "DCF isopole". If we add to this that each element corresponds not to one DCF, but to several, then this "impossibility" will be further aggravated. Please note that if the user wants to see the result of several downloads at the same time, he must use the Download Exchange mode.

When determining the design combinations, logical relationships between loads, reflecting their physical content, and the requirements regulated by various regulatory documents are taken into account.

The following types of logical connections can be distinguished:

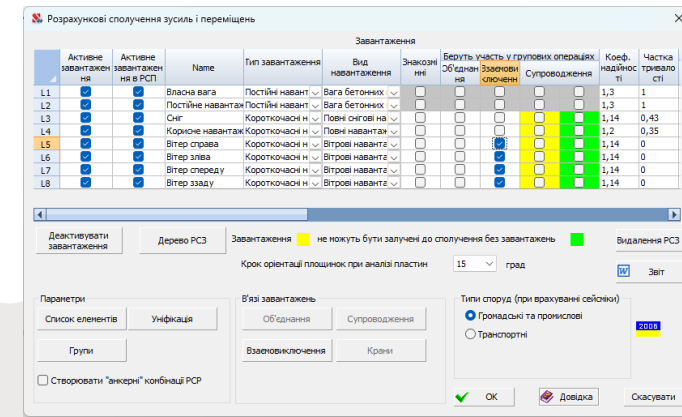
- mutually exclusive, which cannot simultaneously enter into the same combination (for example, wind on the left and wind on the right, seismic action along different coordinate axes, etc.);
- concomitant, when loads cannot independently fall into the calculation combination without the load that generates them. The braking forces of the crane trolley cannot be included in the combination if it does not include the forces from the pressure of the crane wheels, although the load from the crane can act without combination with the braking load. Similarly, the forces from the seismic load cannot be included in the combination without those loads (for example, temporary) that are included in the mass of the structure that determine the dynamic characteristics of seismic motion, although temporary loads can be combined without seismic;
- simultaneously acting, for example, the wind of the windward and leeward sides, if they are indicated in different loads. At the same time, it is necessary to distinguish cases when loads necessarily act simultaneously, and can act separately.

In addition, the description of load characteristics provides for character variability (for the same vector module). Almost all dynamic loads are like this.

Obviously, logical connections cannot be contradictory:

- you can not combine permanent and temporary loads;
- the accompanying load cannot have two mutually exclusive forming loads, etc.

The analysis of the DCS, the obtained maximum values of stresses and displacements in the elements is carried out in the mode of graphical analysis after the calculation is performed.



Calculation management

The calculation can be performed only if the initial data of the current project contains a mandatory minimum of information, that is, the geometry of the structural scheme, a description of the stiffness characteristics of all elements and at least one load.

The calculation is activated from the corresponding section of the Project Tree. After that, the Calculation Options dialog box will appear on several pages.

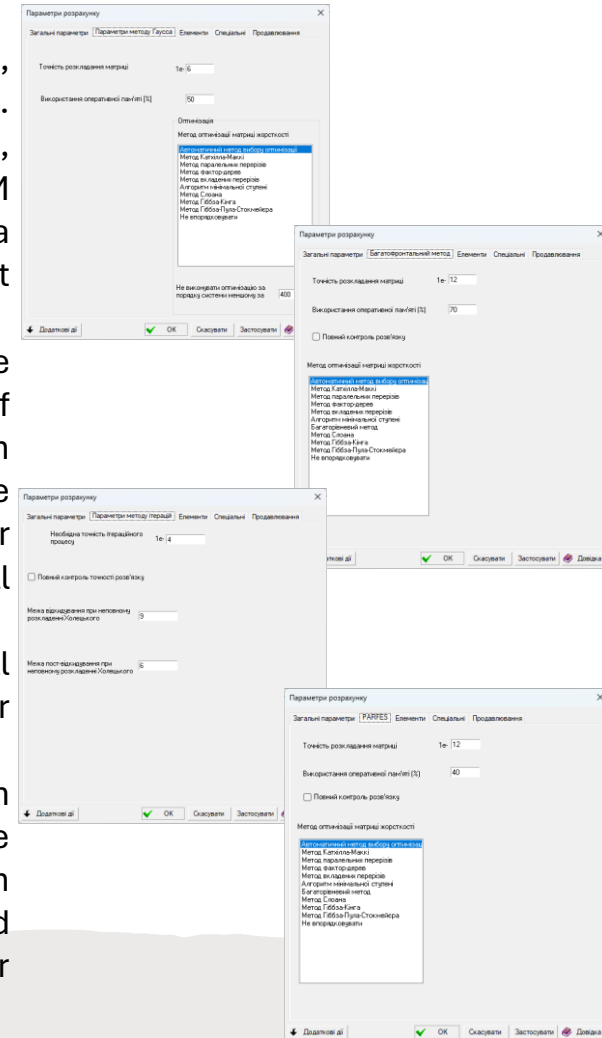
On the "General Settings" page of this window, the processor operating mode ("Full Calculation" or "Continuation of Calculations") is indicated and the solution method (Gaussian, Multifront, Iterative or PARFES) is selected. In addition, on this and other pages, you need to configure the necessary parameters for the computing process.

-When using the Gaussian method, the Matrix Decomposition Accuracy parameter is set on the corresponding page, which determines the minimum value of the stiffness matrix element that is considered non-zero (the default value is 106). If, in the process of decomposition of the matrix, a number less than the specified accuracy appears on the main diagonal, then this situation is interpreted as geometric variability of the system. RAM Usage (%) - Indicates the percentage of RAM used to store information when solving a system of equations (40% by default). In addition, it is possible to choose a method for optimizing the stiffness matrix and specify at what minimum value of the order of the system of equations not to optimize.

-On the Multifrontal Method page, the Matrix Decomposition Accuracy parameter is specified, which determines the minimum size of the stiffness matrix element, which is considered non-zero (the default value is 1012). If, in the process of decomposition of the matrix, a number less than the specified accuracy appears on the main diagonal, then this situation is interpreted as geometric variability of the system. RAM usage (%) - determines the percentage of RAM used to store information when solving a system of equations (70% by default). In addition, it is possible to choose a method for optimizing the stiffness matrix. When the Full Control on Solution token is activated, the accuracy of the solution for all load cases is checked.

-On the parameters page of the Iteration Method, the required accuracy of the iterative process is set and the option of full control of accuracy when solving. The latter provides information about the decision error for each load case. Other parameters are recommended to be changed only at the direction of the developers.

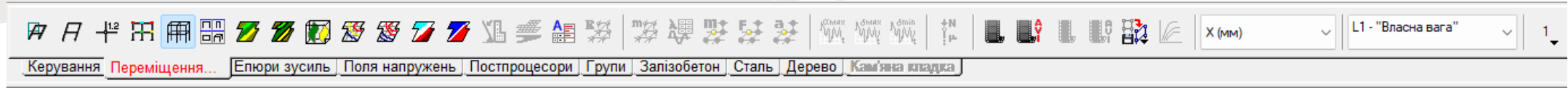
-On the PARFES (Parallel Sparse Direct Solver) page, you set the matrix decomposition accuracy parameter, which specifies the minimum size of the stiffness matrix element that is considered non-zero (default value 1012). If, in the process of decomposition of the matrix, a number less than the specified accuracy appears on the main diagonal, then this situation is interpreted as geometric variability of the system. RAM Usage (%) - Indicates the percentage of RAM used to store information when solving a system of equations (40% by default). In addition, it is possible to choose a method for optimizing the stiffness matrix.



Graphical analysis of results

Graphical analysis of calculation results is performed in the same environment as the preparation of initial data. It only changes the toolbar and adds new display filters.

In this mode, the following types of graphical representation of the results are provided: deformed state of the circuit, color markers and isopoles (for plate elements) of displacements, diagrams of forces in bar elements, stress fields for plate and volumetric elements. In addition, the results of the work of various postprocessors are displayed, groups of nodes and elements are created, etc.



To perform these operations, there are different sections on the toolbar, which can be accessed using tabs:

- Management - access to data, printing, etc.;
- Displacement – analysis of the deformed state;
- Effort plots — analysis of forces in rod elements;
- Stress fields – analysis of stresses and forces in plates and volumetric elements;
- Postprocessors — analysis of the results of post-processors;
- Groups — formation of groups of nodes and elements, including for data transfer to postprocessors;
- Reinforced concrete – examination and selection of reinforcement in the elements of reinforced concrete structures;
- Steel – examination and selection of sections in elements of steel structures.
- Wood – examination and selection of sections in elements of wooden structures.
- Masonry - examination and selection of sites in masonry elements.

Analysis of the joint work of the "foundation-foundation structure" system

To analyze the joint operation of the "foundation-foundation-structure" system, it is recommended to first perform modeling and calculation of the reference design scheme of the building with strict boundary conditions of adjoining the soil base, modeling such an adjoining by installing rigid elms in the supporting part.

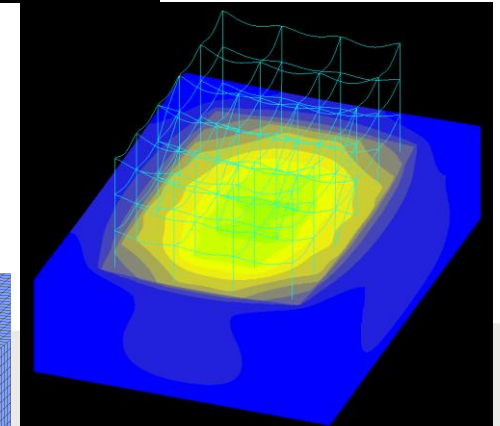
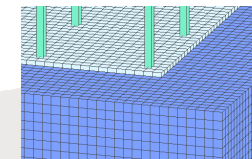
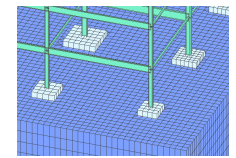
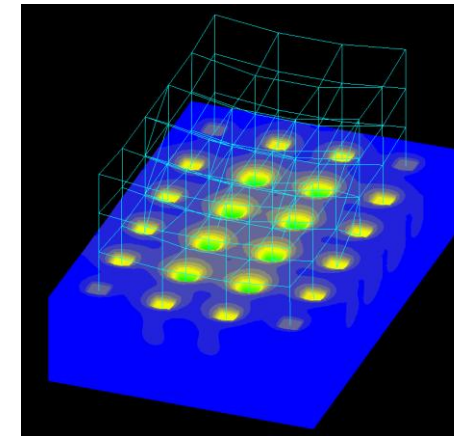
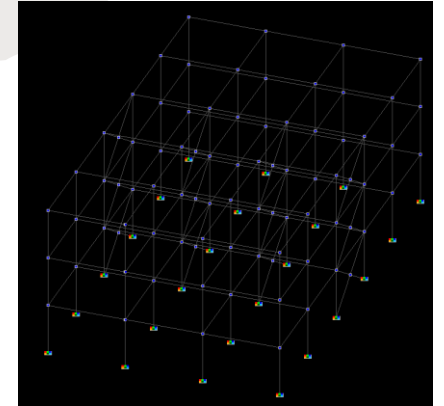
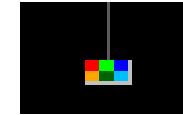
Perform an iterative calculation of the stress-strain state – selection of stiffness of elements (cross-sections of metal and/or wooden elements, thicknesses of slabs, concrete classes, reinforcement, dimensions of the sole of individual foundations, etc.).

After that, attach to the diagram one of the previously considered (the most adequate for this calculation scheme) soil model.

To analyze the change in the stress-strain state, taking into account the joint operation of the "foundation-foundation-structure" system (the value of deformations, changes in DCS, possible insufficiency of previously selected cruelty parameters, etc.).

To draw conclusions about the impact on the stress-strain state of the design scheme of the dimensions of the soles of individual foundations, the rigidity of the foundation slab, the type of structural scheme, the rigidity of the elements of the above-ground structure, engineering and geological conditions, etc., taking into account the joint operation of the "foundation-foundation-structure" system.

Make adjustments to the scheme (if necessary) and perform a repeated iterative calculation.



Formation of design schemes from volumetric elements

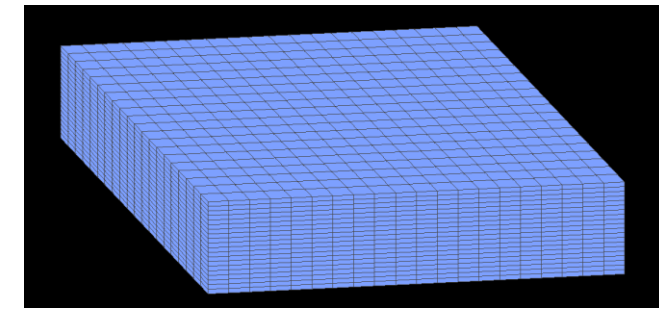
Creating volumetric elements can be performed both by directly entering volumetric elements at nodal points, and by using the "Copy Scheme" tool from plate elements.

To create a model of the soil base in the form of a volumetric soil massif, it is necessary to select the slab using the "Mark Elements" tool.

On the "Diagram" tab, select the "Copy Diagram" tool, and activate the "Copy the visible part of the diagram" mode from the drop-down menu.

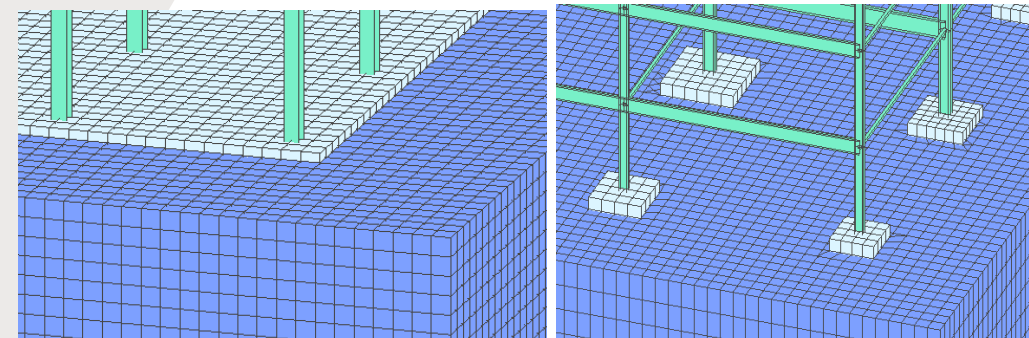
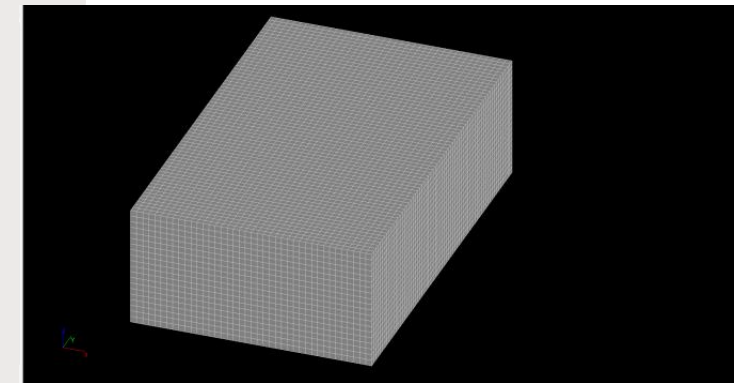
After configuring the copying parameters, a soil mass will be created with the binding of the nodes of the soil mass to the nodes of the previously created foundation slab.

When creating a volumetric soil mass for individual foundations, it is necessary to ensure the connection of the nodes of the foundation elements with the volumetric elements of the soil mass, for the correct calculation.

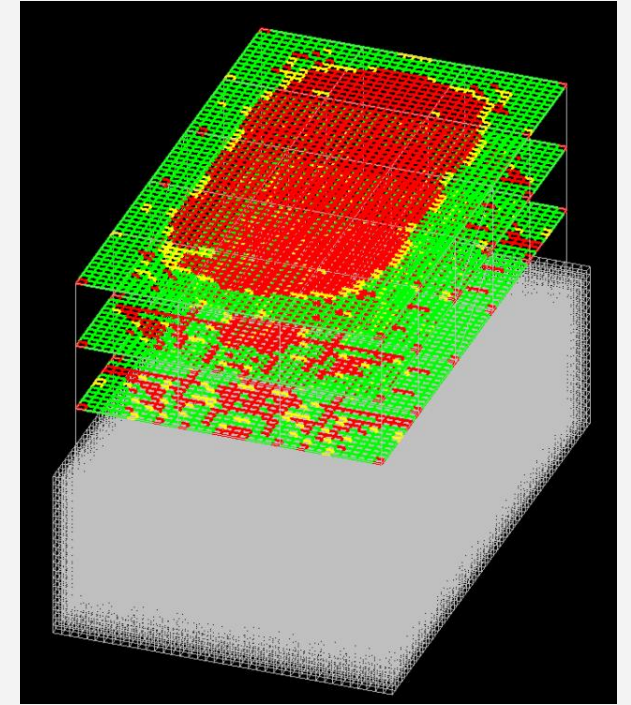
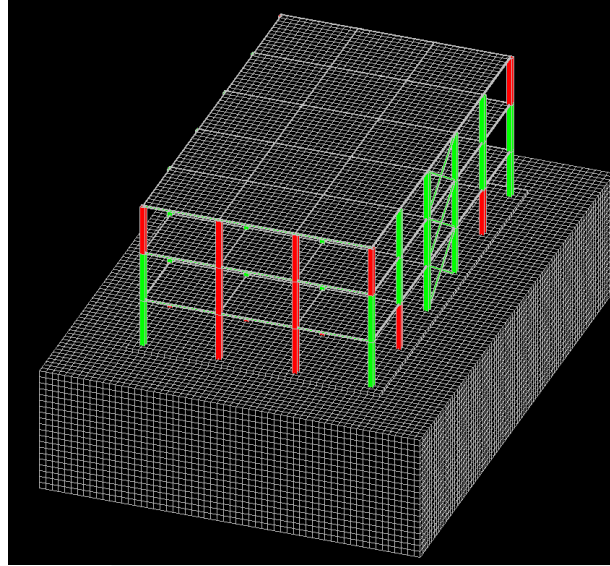
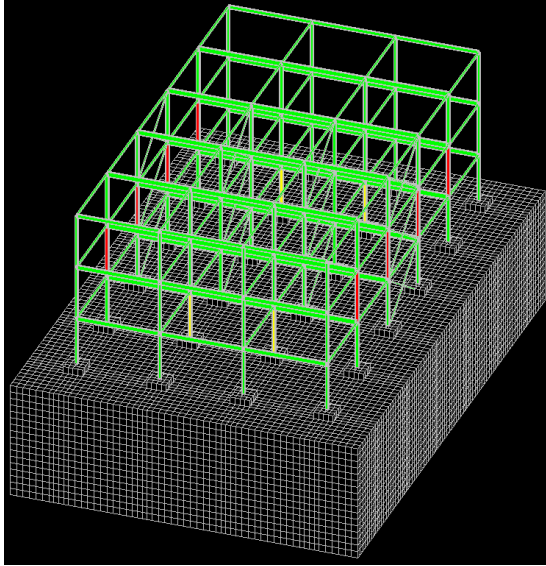


Копіювання схеми

Копіювання видимої частини схеми



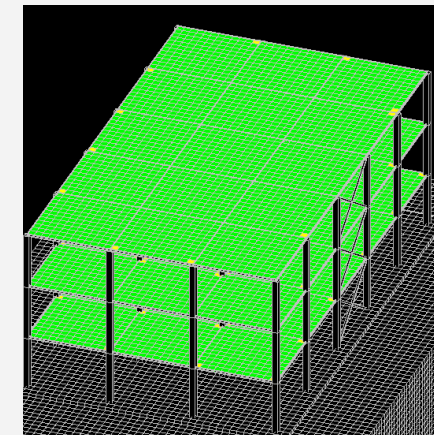
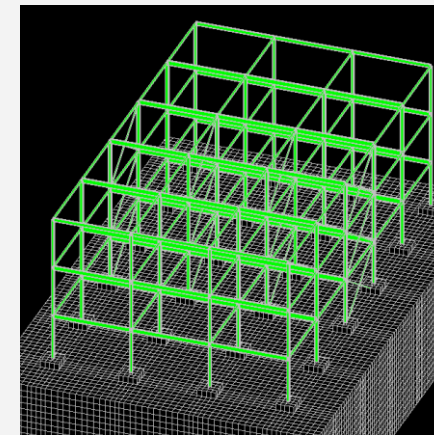
Examples of analysis results taking into account the joint operation of the "foundation-foundation-structure" system



Excess of the bearing capacity of the rod and/or plate elements due to uneven deformations of the base.

The recommended solution is to change the parameters of the foundations (dimensions, sections, rigidity, etc.), strengthen the soil base, change the structural scheme, etc.

It is not recommended to correct the overload of the system elements by increasing the rigidity of the above-ground part of the building (without appropriate justification), although on formal grounds this will also lead to positive results in ensuring the strength and reliability of the system.



Afterword

"Engineering is the art of modeling materials that we don't fully understand into shapes that we can't accurately analyze in order to withstand forces that we can't properly appreciate, so that those around us don't suspect our level of ignorance."

Dr. E. H. Brown(1919–2005)