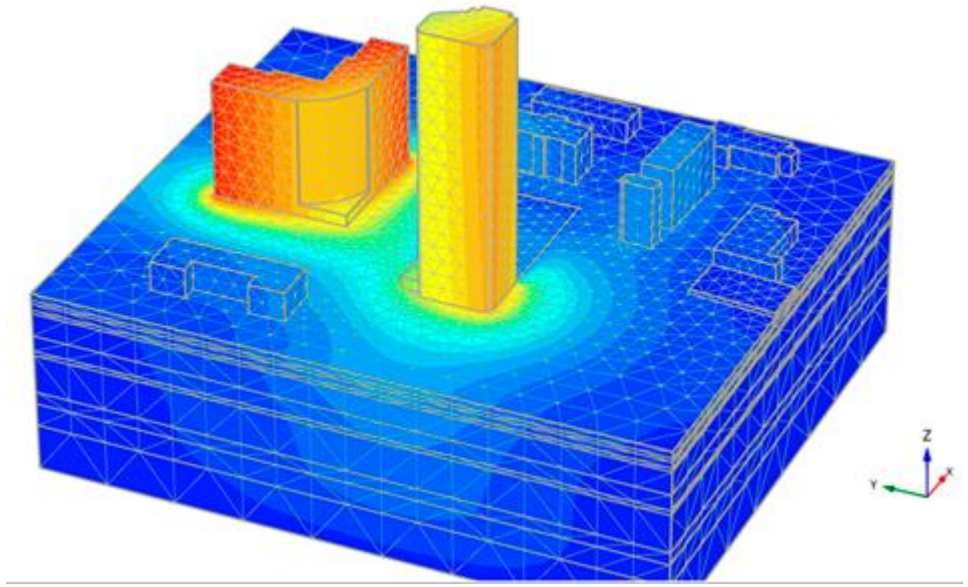
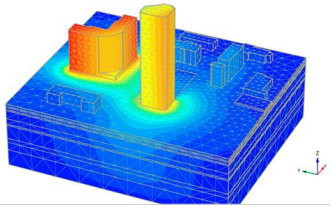
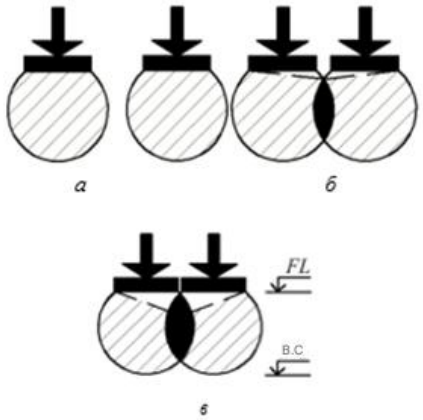
Topic 5. Assessment of the Mutual Influence of Buildings





Features of building design in dense urban development

The construction of buildings near or close to existing ones is a much more difficult task than the construction of a free-standing object. This is due to the fact that the construction of a new building near an existing one causes additional compaction of the foundation, as a result of which the stress in the soil increases, which, in turn, can lead to the appearance of previously built cracks in the masonry of the walls, distortions of openings and staircases, to the displacement of floor slabs, etc. The risk of such deformation is especially high in foundations built on weak soils.

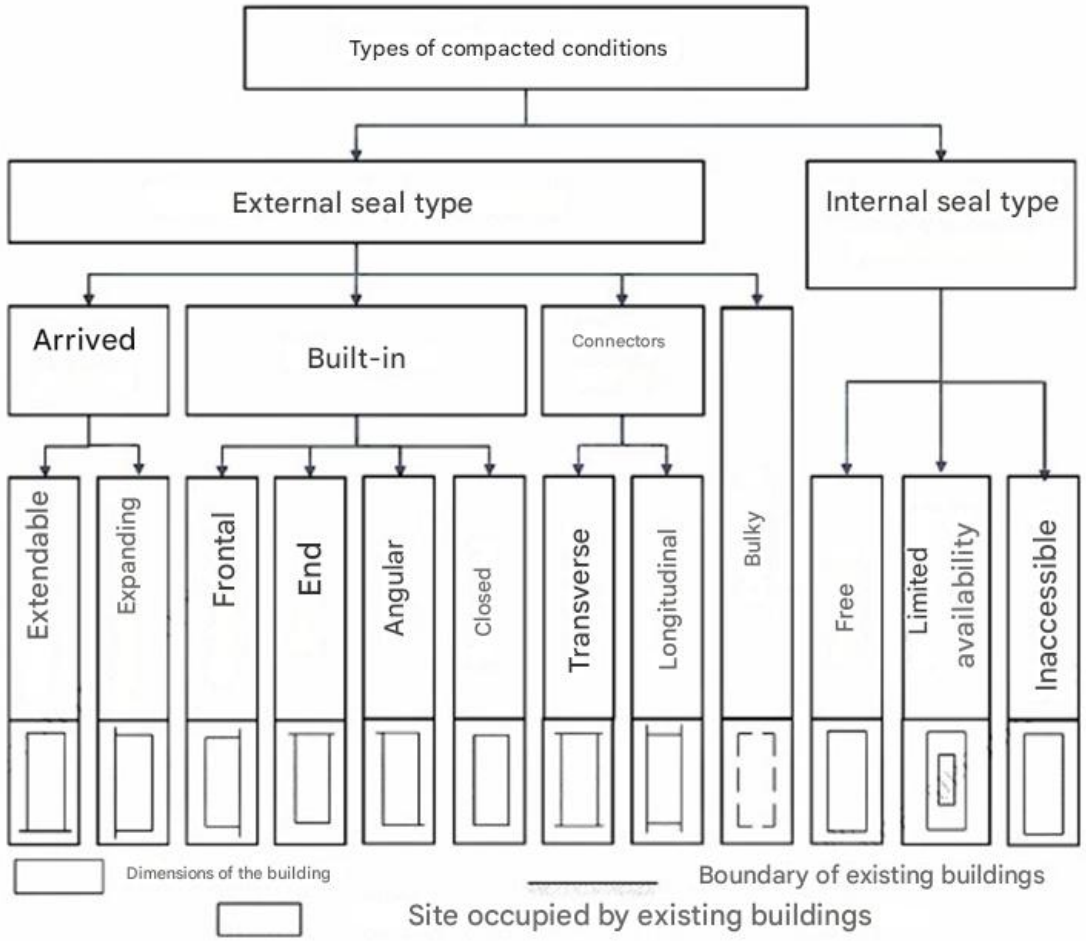


Mutual influence of two foundations (buildings): a, tension zones do not overlap; b, c - depth of active compression zone

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Features of building design in dense urban development

A new building, which is erected in the conditions of dense buildings, due to its load on the soil base, affects the technical condition of adjacent objects existing before the start of new construction, which are in the zone of its influence, including buildings, structures, engineering networks, landscaping elements, etc.



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Features of building design in dense urban development

Analysis of potential mutual influence is carried out taking into account the following factors:

— interaction of buildings at the construction stage;

— interaction of buildings at the stage of operation;

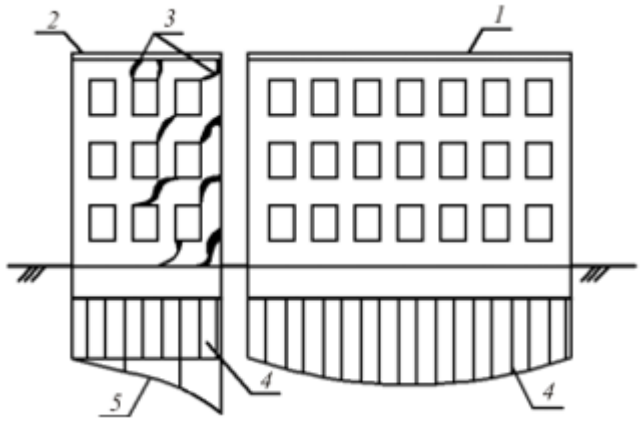
— mutual influence of buildings in the event of a fire;

— mutual influence of buildings in difficult engineering and geological conditions;

— mutual influence of buildings in case of damage due to overtime loads.

These factors are taken into account at the stages of pre-design and design work during the development of complex constructive, organizational and technological measures for all stages of the existence of a new building.

The design of construction of facilities is carried out in accordance with the current regulatory framework in construction, taking into account additional requirements for the design features of construction in dense buildings, set out in DSTU 9271:2023 Guidelines for the design and execution of work in dense buildings.



Deformations during the construction of a new building next to the existing one: 1 – new building under construction; 2 – existing building; 3 – places of cracking and development of structural damage; 4 - subsidence area of foundations; 5 – area of additional subsidence of foundations

Features of building design in dense urban development

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In the case of designing objects in dense buildings, measures are provided to minimize the negative impact of new construction.

The main reasons for deformations of objects adjacent to a new building are due to interaction through the soil massif as follows:

— changes in hydrogeological conditions, including flooding, associated with the barrage effect during underground construction, or changes in the groundwater level;

— an increase in vertical stress in the base under the foundations of nearby objects as a result of construction near them;

— arrangement of pits or change of plan-height marks;

— technological factors, such as dynamic influences, the impact of the arrangement of all types of piles, foundations of deep embedding and enclosing structures of pits, the impact of the arrangement of injection anchors, the impact of special types of work (freezing, injection, etc.);

— negative processes in the soil mass associated with the performance of geotechnical works (sufosis processes, formation of quicksands, etc.).

Substantiation of the zone and indicators of impact on the surrounding buildings during construction is carried out at the design stage by making calculations using methods of information and mathematical modeling. For critical objects (responsibility class CC2 and CVS) in conditions of dense buildings, mutual impact calculations are performed as part of the project and a duplicate calculation within the framework of scientific and technical support (STS).

Features of building design in dense urban development

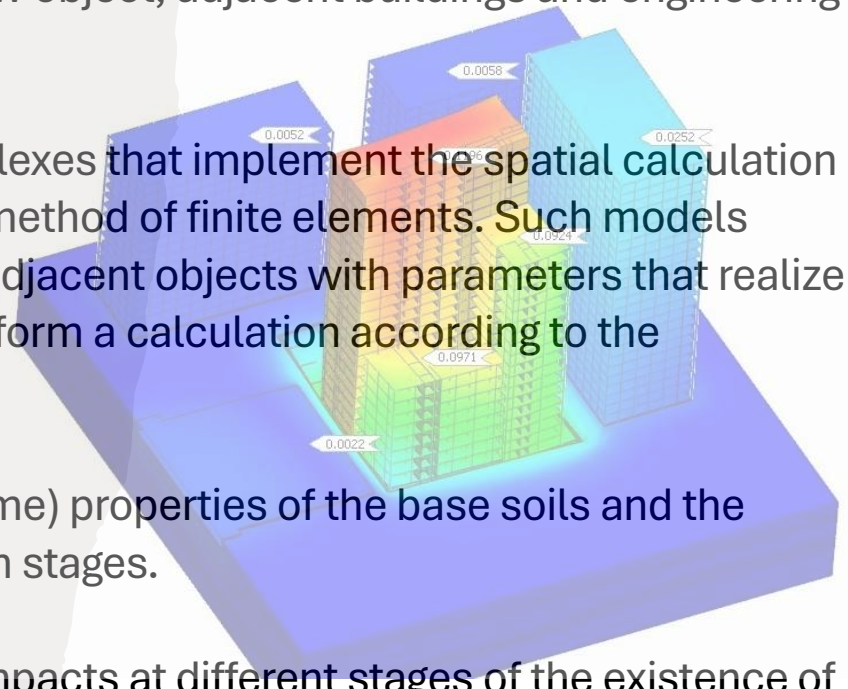
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- The development of compensatory measures for the protection of nearby objects is carried out as part of the project of a new building. Measures to protect the adjacent buildings, their design solutions, methods of work and their volumes are interrelated with the decisions made regarding the new building, which are taken on the basis of the analysis of their interaction.
- The project of a new building should provide for a set of instrumental (and other) observations (monitoring) of the existing adjacent buildings.
- Before the start of design, the adjacent buildings are inspected in accordance with DSTU 9273:2024. If during the inspection of nearby objects a violation of the integrity of their structures and foundations is revealed, this should be recorded in the survey report.
- When laying, shifting or reconstructing several underground structures at one construction site (street, passage), regardless of their number and departmental affiliation, it is advisable to develop a comprehensive mutually agreed project. In order to avoid repeated excavation of the roadway, the projects, if possible, provide for the arrangement of exits of underground structures beyond the red lines.
- The laying of several underground communications on one street (passage), if possible, is designed in special passage collectors or combined in one route.

Methods for taking into account the mutual influence of foundations and buildings

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Calculations of the system "new building - soil mass - existing buildings"
For critical objects in conditions of dense buildings, impact calculations are carried out by creating a digital information model of the new object and the surrounding buildings using the methods of information and mathematical modeling, which takes into account the interaction of the soil base, the design of the new object, adjacent buildings and engineering networks.



When performing calculations, preference is given to modern software complexes that implement the spatial calculation model of the system "new building — soil mass — existing buildings" by the method of finite elements. Such models implement the work of the soil mass and the structure of new buildings and adjacent objects with parameters that realize the nonlinear nature of deformation. In justified cases, it is permissible to perform a calculation according to the calculated section.

The digital information model takes into account the rheological (change in time) properties of the base soils and the potential change in groundwater levels both at the construction and operation stages.

As a result of the calculations, the most dangerous zones and indicators of impacts at different stages of the existence of a new building are determined, taking into account possible factors of influence.

When performing calculations using information and mathematical methods, isofields of soil mass deformations are obtained within the calculation model.

Methods for taking into account the mutual influence of foundations and buildings

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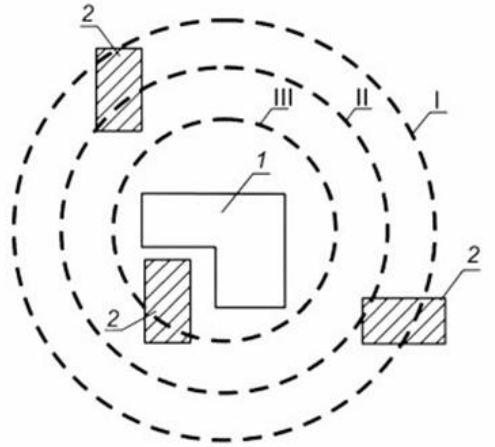
To analyze the zone of influence of the construction of a new building, studies of isopoles of subsidence of various gradations at the stage of construction and operation of a new building and adjacent objects are performed. At the same time, there are three conditional zones of influence:

— the zone of "small deformations", limited by soil subsidence of 3-10 mm, while the general zone of influence is examined with the determination of potential deformations in the road surface, shallow communications, etc. (zone I);

— zone of "large deformations", limited by soil subsidence from 10 mm to permissible values of deformations, the allocation of such a zone is necessary to determine the list of buildings and structures for which it is necessary to check additional subsidence (zone II);

— the zone of "excess of permissible deformations", limited by soil subsidence exceeding the value of permissible additional subsidence in accordance with Annex B of DBN V.1.2-14:2018 for a certain structural type of buildings of the surrounding buildings in the appropriate technical condition. The allocation of such a zone of influence is necessary to determine the zone within which overtime additional subsidence occurs (zone III).

To calculate the impact in simple engineering and geological conditions for buildings of responsibility class CC1 and CC2, it is possible to apply analytical calculation methods.



Conventional signs:

1 - new building;

2 - adjacent objects;

I – the boundary of the "small deformation" zone;

II boundary of the zone of "large deformations";

III – the boundary of the zone of "exceeding permissible deformations".

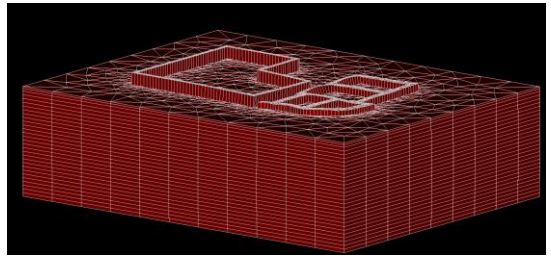
Methods for taking into account the mutual influence of foundations and buildings

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Information modeling

Based on the initial data, during the design of a new building in compacted conditions, calculations of the stress-strain state of the soil mass are performed and the impact of new construction at the construction stage and after its completion at the stage of operation is assessed. Usually, numerical modeling of the stress-strain state of the soil mass is carried out using the finite element method and modern calculation programs.

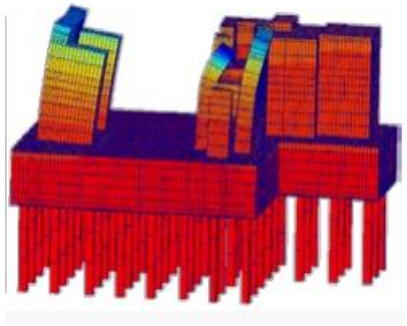
For this purpose, software complexes are used that implement the finite element method in displacements, as well as ordinary and curved isoparametric elements with quadratic approximation functions.



Systematization of software capabilities in conjunction with the system of requirements for ensuring the strength, stability of a new building and adjacent objects makes it possible to develop an algorithm and a calculation model of the impact of new construction on adjacent objects.

The main methods and software complexes for calculating the impact of a new building on nearby objects are as follows: SCAD Office PC, LIRA PC, PLAXIS PC, Soil SS, Midas, Z-Soil, RS, and for spatial calculation of building structures — SCAD Office PC, LIRA PC, PLAXIS 3D PC, SAPPHIRE-SD PC, ROBOT, MIDAS and other similar complexes.

Systematization of factors influencing construction works on adjacent buildings makes it possible to develop a system of typical organizational and technological solutions to prevent emergencies that may arise during the construction process, and forecasting them taking into account the data of the instrumental monitoring system for the object and the surrounding buildings. The results of monitoring are subject to analytical assessment of the impact using mathematical modeling, taking into account transformational changes in the stress-strain state of the soil mass at the base of buildings and the adjacent massif.



The creation of an information model of a building based on BIM technologies is solved by parametric design, which is based on the creation of a model using the parameters of the model elements and the relationships between these parameters. All software complexes involved in a particular project have their own model options.

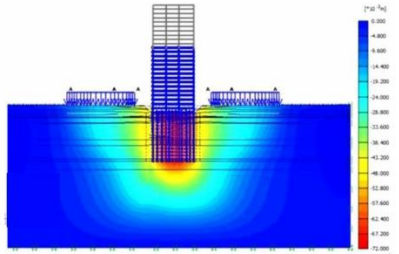
The parametric model of the building integrates a three-dimensional model and a model of the behavior of the elements (history of changes). On the basis of such an information model, project documentation is formed.

Methods for taking into account the mutual influence of foundations and buildings

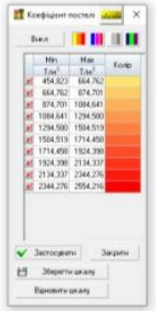
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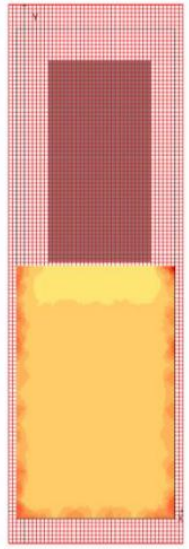
Information modeling

The calculation of the foundations and foundations of existing buildings according to the I group of boundary states is performed in the following cases:
— arrangement of pits near nearby objects;
— arrangement of workings and trenches (including under the protection of thixotropic solutions) near nearby objects;
— change of plan-height marks near the outer walls of nearby objects;
— change in pore pressures in the soil mass in case of incomplete consolidation process;
— transfer of additional loads and influences to the existing foundations of nearby objects.



The purpose of the calculation for group I boundary states is to ensure the strength and stability of the foundation, to prevent the displacement or overturning of the existing foundations.
The calculation of the base for group I of boundary states is performed in accordance with the requirements of DBN B.1.2-14:2018. At the same time, calculation methods based on the search for the most dangerous sliding surface, which separates the soil mass from the stationary part of the massif in the event of a landslide, are used as preferential methods (for example, the methods of round-cylindrical or broken surfaces, the method of logarithmic spiral, the method of variable mobilization of shear resistance, etc.).





In the case of designing foundations or enclosing structures of pits (retaining walls, separating walls), by the methods of driving and vibration immersion of piles or sheet piles, a test calculation is performed for the dynamic strength of the load-bearing structures of the existing building, closest to the elements that are submerged.
The calculation of the foundations of existing buildings or structures according to group II of boundary states is performed in all cases if they are located in the zone of influence of new construction.

Methods for taking into account the mutual influence of foundations and buildings

Requirements for determining the deformations of the base of the structure depending on the types of impacts during construction near it

Additional deformations of buildings or structures during the calculation according to group II of boundary states are determined depending on the type of impact in accordance with the table.

Type of influence	Additional deformations that determine				
	average or maximum settlement of the foundation, s	relative difference in foundation settlements, As/L	foundation tilt, and	horizontal movement of the foundation or buildings, i	relative horizontal displacement, Ди/L
Changing hydrogeological conditions	+	+	-	-	-
Increased load on the foundation during the construction of a new building	+	+	+	-	-
Construction of a pit near a building or change of planning marks	+	+	+	+	+
Dynamic influence	+	+	-	-	-

Methods for taking into account the mutual influence of foundations and buildings

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During construction near nearby objects, the calculation of their foundations and foundations for deformations must be carried out, taking into account two conditions:

$$s + s_{ad} \leq s_u^{повн},$$

$$s_{ad} \leq s_{ad,u},$$

s — deformation of the foundation, which was completed before the start of new construction;

$s_u^{повн}$ — Limit value of the total deformation of the base;

s_{ad} — additional deformation of the base caused by new construction;

$s_{ad,u}$ — limit value of additional deformation of the substrate caused by new construction.

Selection of methods for laying foundations, taking into account the impact on adjacent buildings and probable changes in engineering, geological and hydrogeological conditions

State building regulations of Ukraine

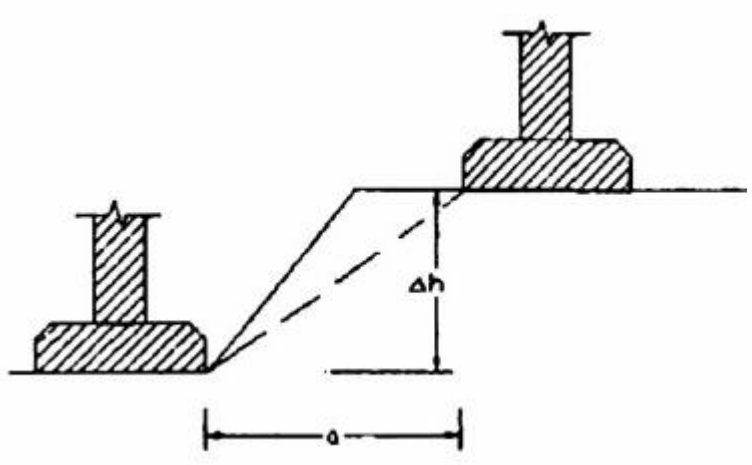
If it is necessary to lay the foundations of a new building in a pit without a fence below the mark of laying the foundations of nearby objects, the permissible difference in the embedding marks is determined, taking into account the following condition:

$$\Delta h \leq a(\operatorname{tg} \varphi_1 + c_1/p),$$

a — distance between foundations in the light;

φ_1 and c_1 — respectively, the calculated values of the angle of internal friction and specific adhesion of the soil, which are taken for calculation according to the first group of boundary states;

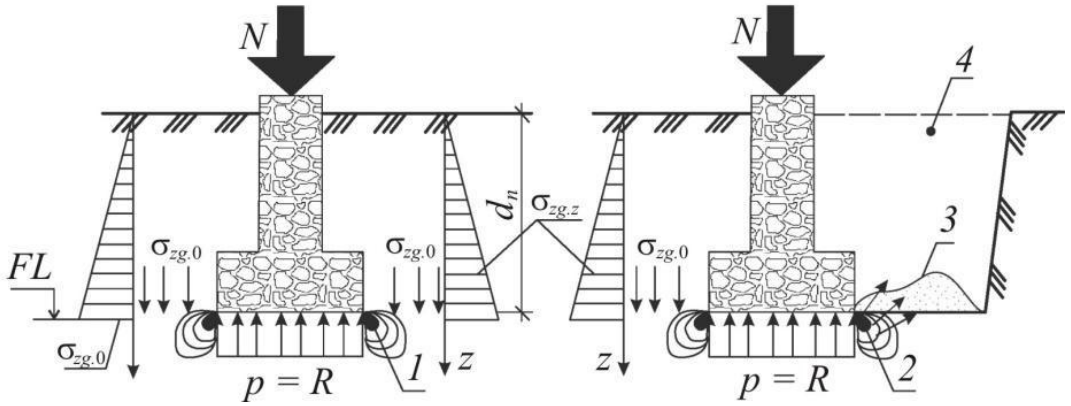
p — average pressure under the sole of the foundation of nearby objects from the design loads determined for the calculation of the base of bearing capacity.



If the condition cannot be met or the values of deformations of nearby objects from the impact of the new building exceed the maximum permissible values, measures are taken to reduce the impact of the subsidence of the new building on nearby objects.

Selection of methods for laying foundations, taking into account the impact on adjacent buildings and probable changes in engineering, geological and hydrogeological conditions

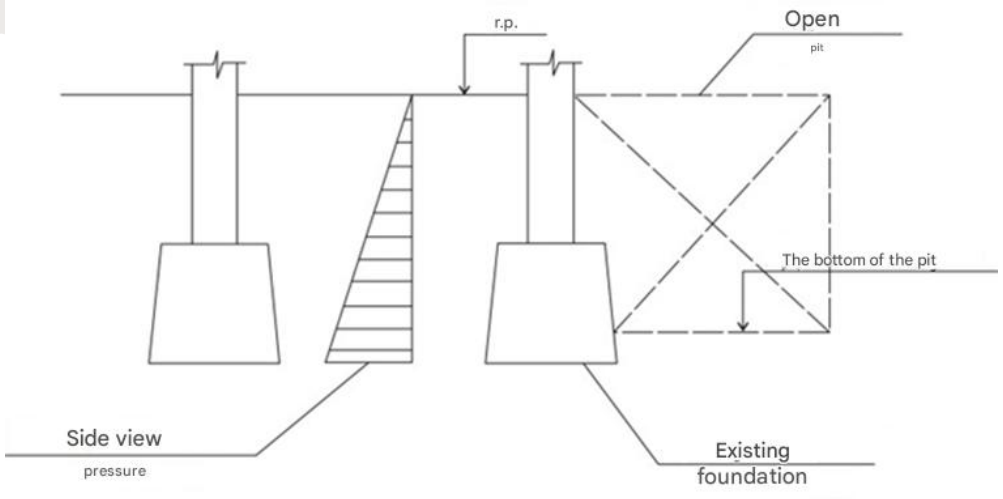
When digging pits near existing foundations, vertical and horizontal stresses in the soil mass below the bottom of the pit and in the vicinity of it are reduced. In the soil mass outside the pit, including under existing foundations, horizontal stresses are sharply reduced due to the removal of loading, and vertical stresses depending on the pressure transmitted by the foundation to the foundation remain unchanged. As a result, plastic deformations of the soil develop, accompanied by its extrusion from under the foundation towards the pit. The intensity of their development depends on the relative location of the sole of the existing foundation and the pit.



Vertical stress based on structures:
a- to the development of a neighboring pit;
b - after its development;
1 – zones of plastic deformations of the soil;
2 - zones of possible soil digging;
3 - raising the bottom of the pit;
4 - a pit dug near the foundation;

Selection of methods for laying foundations, taking into account the impact on adjacent buildings and probable changes in engineering, geological and hydrogeological conditions

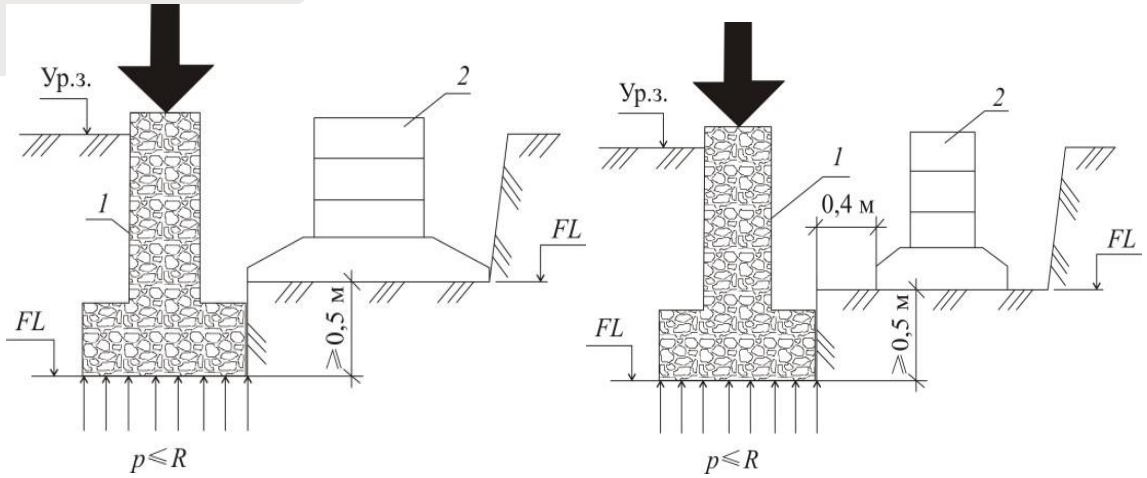
If the existing building does not have a basement, and the pit of the new one must be opened close to the foundations of the existing one, the active lateral pressure of the soil on the wall of the existing building, directed towards the open pit, should be taken into account.



Lateral pressure of the soil on the wall of an existing building when tearing off a pit for the foundations of a new building

Selection of methods for laying foundations, taking into account the impact on adjacent buildings and probable changes in engineering, geological and hydrogeological conditions

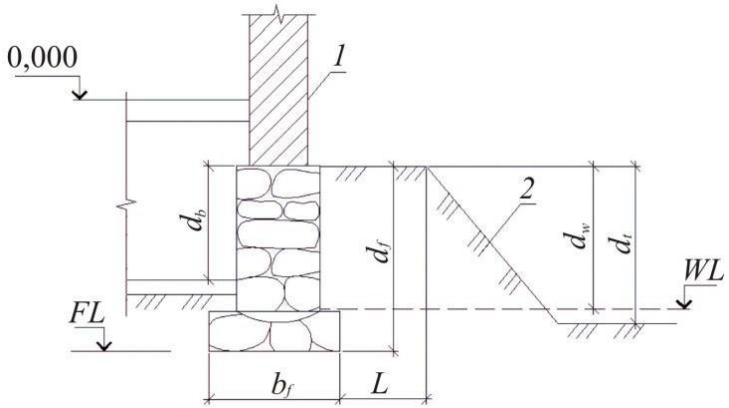
If the average pressure under the sole of the existing foundation (in the case of direct adjacency) is p ≤ R (R is the design resistance of the foundation soil), then when the bottom of the pit is located 0.5 m or more higher than the sole of the existing foundation, as a rule, the soil is not squeezed out from under the foundation sole. However, it must be borne in mind that the foundation of the building to be added may be on the insufficiently compacted backfill of the previously erected foundation and therefore will receive a greater settlement than other foundations.



The location of the existing 1 and 2 designed foundations, in which the squeezing of soil from under the existing foundation is excluded: a - adjacent foundations closely; b - adjoining foundations at a slight distance.

Selection of methods for laying foundations, taking into account the impact on adjacent buildings and probable changes in engineering, geological and hydrogeological conditions

When developing a project for the execution of work, depending on the ratio of the depths of the designed pit dt, the laying of the sole of the existing foundations df and the groundwater level dw, the following provisions must be taken into account):
At dt ≤ (df - 0.5) and dt ≤ dw, the development of the pit is possible without the use of special measures.
At (df – 0.5) < dt < df and dt ≤ dw, the excavation of the pit within a strip 5 m wide, counting from the edge of the existing foundation, should be done with grippers no more than 1.5 m along the length of the junction><<. carrying out the following activities:
performance of work on one gripper should not exceed two days;
The choice of the method of soil development should be carried out taking into account the stressed state of the soils on the basis of existing foundations. The use of an excavator with a dragline bucket, ball or wedge-hammer at a distance closer than 20 m from existing buildings, as well as an explosive method, is unacceptable.
If the pit with a depth of dt < df is adjacent to the foundations of existing buildings, you should, as a rule, use a wooden technological sheet pile, driven along the edge of the foundation to a depth of 2-3 m below the sole. In this case, it is necessary to calculate this basis of stability, taking into account the method of developing the pit.
In cases where a pit with a depth of dt < df is not adjacent to the existing foundations, it is necessary to take into account the following provisions: db≤ df, L ≤ 1.5df, bf ≤ L - the pit is located outside the prism of the flogging, the stability of the foundation is ensured in advance; df - db ≤ df - dt at L ≥ 0 and dw > dt - the stability of the foundations and foundation is ensured;
dt≤ df, 0 ≤ L ≤ 1.5df – the calculation is carried out according to the first limit state.
At dt > dw, before starting the development of the pit, it is necessary to hammer in a process sheet pile (Fig. 2.4.5) in order to reduce or prevent the inflow of groundwater; such a sheet pile must be immersed to the underlying water stop (see Fig. 21, a) or to a depth determined by the ratio L≥ (2.2dt – 1.1dw),
where L is the required length of the sheet pile (from the ground).
It must be remembered that the length of the sheet pile, determined according to the above formula, does not guarantee the stability of the soils of the base of existing foundations, and this issue is subject to a special calculation.
The development of the pit and the construction of foundations should be carried out by grippers.



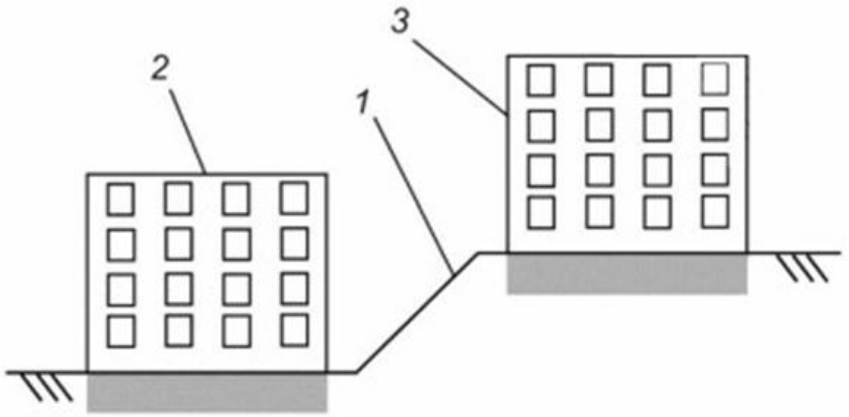
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Constructive measures to reduce the impact on existing buildings

During the arrangement of pit slopes, the optimal geometric parameters of soil slopes and slopes between buildings are selected to minimize mutual influence.

The physical and mechanical parameters of the soil mass of the foundations of buildings, the hydrogeological situation, the type of foundations of buildings that are subject to mutual influence are taken into account.

Calculations are carried out according to the criteria given in the provisions of DSTU-N B V.2.1-32.



Conventional signs:

1 - slope;

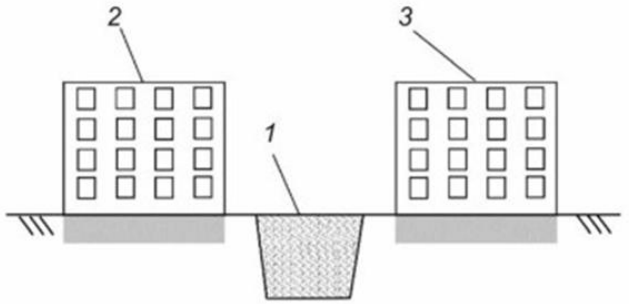
2 - new building;

3 - adjacent object.

Constructive measures to reduce the impact on existing buildings

Consolidation of the soil mass using cementation, jet technology or chemical fixing. It is usually used in soils that have high permeability for fixing substances. A limitation for the application is the significant filtration flow of groundwater in the massif during applications, such as silication or cementation.

The device of thin vertical fixed soil masses made using jet technology is used in case of a high pace of construction, which, in addition to the possibility of limiting the area of influence, also affects the restriction of filtration flows.

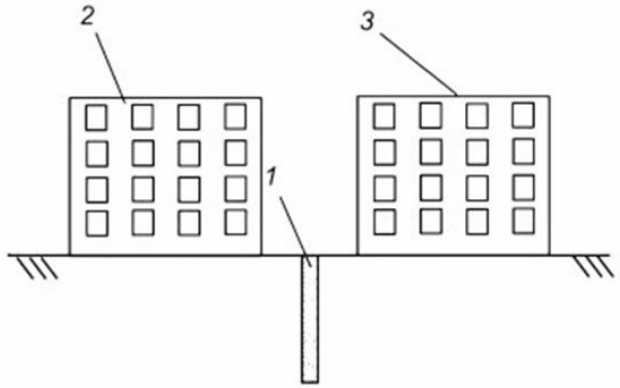


Conventional signs:

1 - fixed array;

2 - new building;

3 - existing building.



Conventional signs:

1 - jet array;

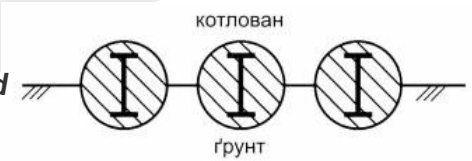
2 - new building;

3 - existing building.

Constructive measures to reduce the impact on existing buildings

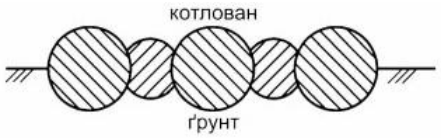
Tongue-and-groove fencing device of various types

Installation of wells in stable soils with the installation of rigid reinforcement with the following This type of elements is used in dry stable soils in pre-drilled wells.



Pile Filling Device with Jet Columns The combination of reinforced piles and jet column filling provides high lateral pressure resistance and water resistance to filling heights

Installation of sheet pile fencing from Larsen sheet pile The use of inventory sectional elements of the Larsen type makes it possible to reduce the time for the installation of the wall structure. A significant limitation in the conditions of compacted buildings is the methods of immersion of sheet pile sections. Dynamic methods of vibration immersion or shock are usually avoided.

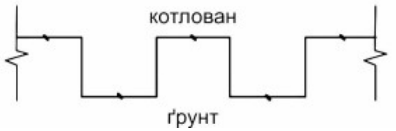


Installation of sheet pile fencing from Z-sheet pile The use of inventory sectional elements of the "Z" type makes it possible to reduce the time for the installation of the wall structure. A significant limitation in the conditions of compacted buildings is the methods of immersion of sheet pile sections. Dynamic methods of vibration immersion or shock are usually avoided.

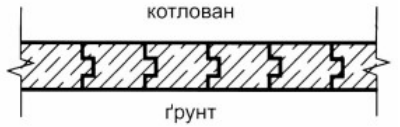


Installation of walls with the help of micropiles with keys Micropiles of rectangular section with keys in conditions of compacted buildings using the method of immersion by crushing provide reliable insulation from pressure of shallow foundations of nearby objects and groundwater for shallow pits.

The use of the "wall in the ground" technology made of monolithic reinforced concrete in the conditions of compacted buildings ensures the minimization of deformations of the foundations of nearby objects, the prevention of filtration and sufosis, as well as the possibility of installing deep pits.

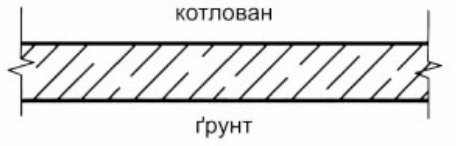


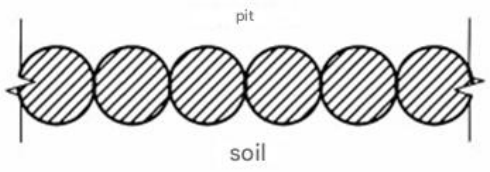
Construction of a "wall in the ground" from prefabricated elements The use of the technology of a prefabricated "wall in the ground" in conditions of dense buildings ensures the minimization of deformations of the foundations of nearby objects, the prevention of filtration and sufosis, as well as the possibility of arranging deep pits. The limitation of the application of the technology is the complexity of the structural joining of individual panels with ensuring their water resistance, as well as the possibility of changing the hydrogeological conditions of the building site and the complexity of the complex of equipment used.

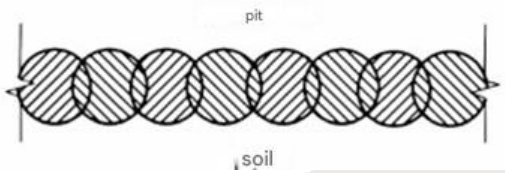


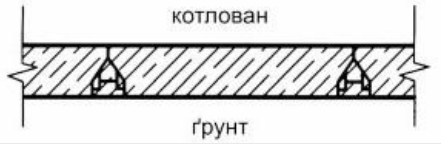
Arrangement of rows of piles adjacent to each other A row of piles allows you to arrange screened walls to a considerable depth. With this design scheme, the wall is permeable, but at the same time the filtration flow reduces its speed. A significant limitation of the use of a number of piles is the technology of bored injection and bored piles, which may affect the stability of the foundations of nearby objects in the process of their construction.

Arrangement of a series of borage piles A number of borage piles provides greater isolation of groundwater filtration flows compared to a series of piles (8.4.8). The limitation of the design scheme is the complexity of the technology of installing a number of borage piles in a template, which ensures the planned design position of the piles relative to each other and compliance with the correct pace of pile installation.







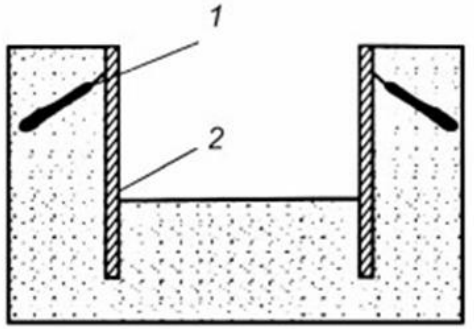


Constructive measures to reduce the impact on existing buildings

Installation of anchor and dowel fasteners during the construction of deep pits in the conditions of compacted buildings Anchor fasteners structurally consist of a root part located outside or crossing the border of the prism of displacement of the soil massif, and a rod connecting the root of the anchor with the structure of the pit enclosure.

A type of anchoring is a ground dowel - a horizontal or inclined reinforcing element or a bored injection micropile. The dowel is fixed without pretension in the soil slope, the vertical wall of the excavation during its development, as well as in the natural slope to increase its stability.

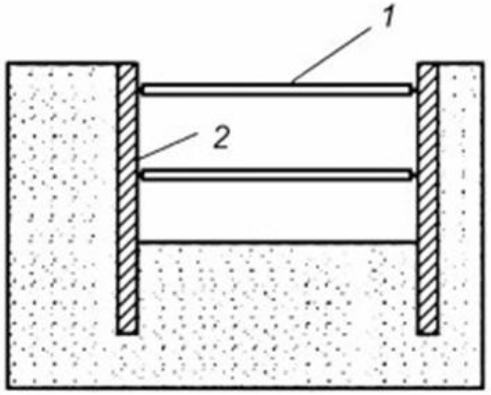
Execution of spacer elements during the construction of deep pits in conditions of compacted buildings The installation of metal spacer elements is carried out from different profiles, taking into account the load on them. The use of such structural elements in the compressed conditions of the pit restricts the freedom of movement of workers and the delivery of materials and structures to the installation area.



Conventional signs:

-1 - anchor (nail);

-2 - pit fencing.



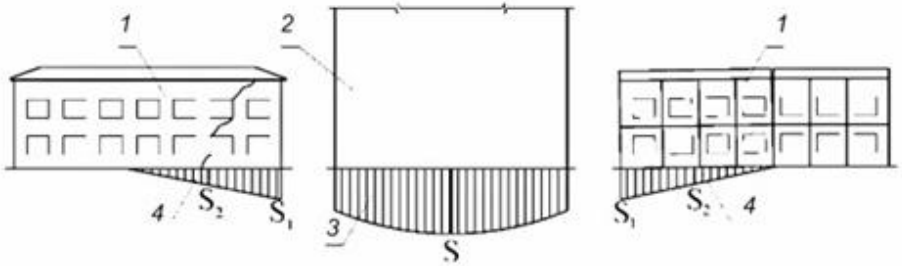
Conventional signs:

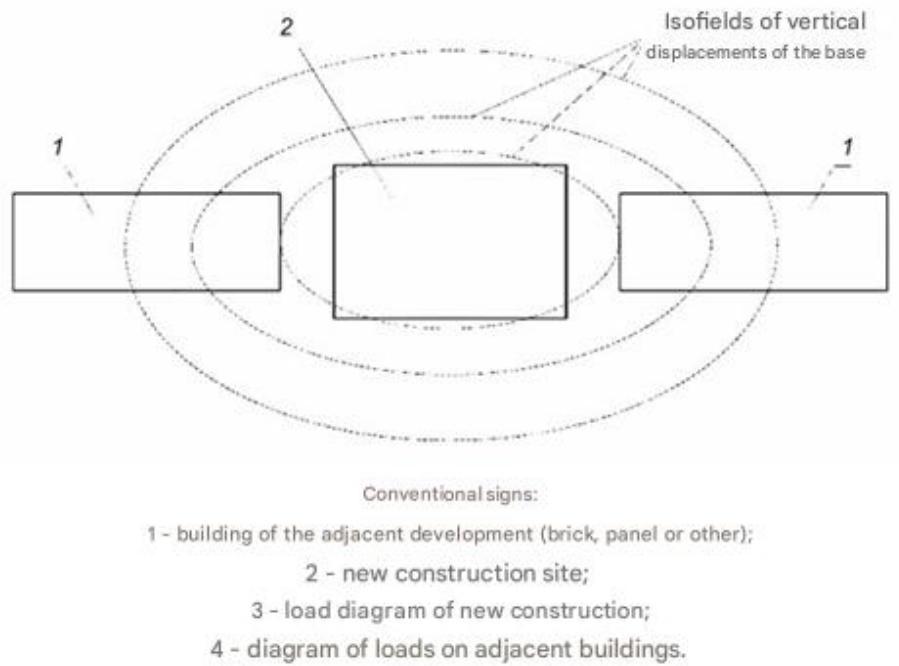
1 - spacer element;

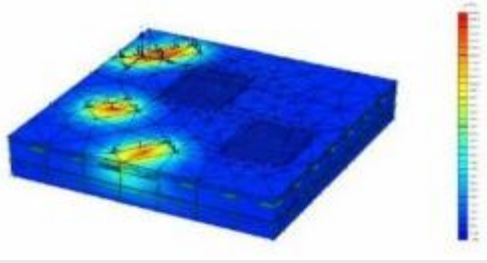
2 - pit fencing.

Creation of a calculation scheme of mutual influence

The impact of new construction on the operational suitability of adjacent buildings is a multi-factor task, the solution of which requires certain assumptions and schematization.
The possibility of using analytical models is limited by simple equations, regular regions and constant boundary conditions. In the case of using analytical models, the calculation of the size of the zone of influence (subsidence funnel) of new construction on the soil base of nearby objects is carried out on the basis of the methods of round-cylindrical or broken surfaces, logarithmic spiral, variable mobilization of shear resistance and others, which to some extent limits the informative value of operational decision-making.
Available software methods for calculating such an impact provide for the presence of a mathematical model as part of the system "new building — soil mass — existing buildings".
Information and mathematical modeling using the finite element method (ITU) makes it possible to quickly choose the option of compensatory solutions, taking into account the dynamics of deformations of the new building and adjacent buildings.
The basis of the physical concept of ITU is the breakdown of the mathematical model of the design into components (subareas) of simple geometry. The mechanical behavior of each element is expressed using a finite number of degrees of freedom or the values of the desired functions in a set of nodal points. The behavior of the information-mathematical model is approximated to the behavior of the discrete model obtained by adding all the elements.







Creation of a calculation scheme of mutual influence

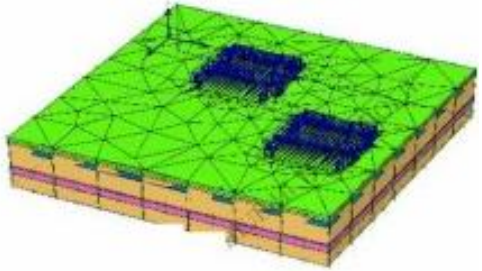
Modeling of the stress-strain state of the soil mass and its changes during the construction process is carried out using the following programs: PC SCAD, PC "LIRA", PC PLAXIS, PSS "SOIL", Midas, Z-Soil, RS, etc. Despite the differences in the information and mathematical models involved, they use the same list of initial data.

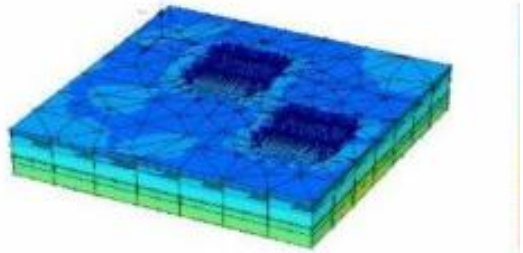
The initial data for the calculation are: engineering and geological conditions of the base soils and their actual location; mutual geometric arrangement of recessed elements of existing structures of nearby objects and new buildings; hydrogeological situation of the building site; permanent, long-term, temporary loads from nearby facilities and new buildings. To describe the construction site, the soil characteristics base (IGE), coordinates and marks of the wellhead, as well as the characteristics of the soil layers in each well are specified. Based on these data, a spatial model of the soil base is formed, and the relief of the bottom surface is built according to the marks of the top of the wells. The load from nearby objects and new buildings is set by the complete structure of objects with full characteristics of their materials or by a load stamp with a reliability factor, applied to the level marks of the foundation sole. The main result of the calculation is to obtain the zone of influence (subsidence funnel) at the stages of construction and operation of a new building with the possibility of taking into account the impact of compensatory measures.

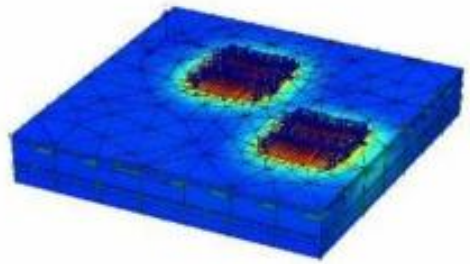
To model nonlinear problems that depend on time and anisotropic properties of soils and rocks, various soil models are used: from the Mohr-Coulomb model for quick calculation, to the model of weak soil with a creep effect that depends on time and compaction of normally consolidated weak soils.

The "SOIL" system implements the calculation of stiffness parameters of soil and pile bases in accordance with the Winkler and Pasternak soil models. The system of SS "GRUNT" PC "LIRA" is focused on the automatic determination of the coefficient of bedding variable in terms of the area of the foundation slab based on a three-dimensional soil model. According to this model, over the entire section of the slab, the values of vertical stresses are determined, which depend on the loads on the slab and adjacent buildings, as well as the depth of the compressible thickness and subsidence are calculated. The values of the bedding coefficients for each final element are automatically transferred to the general computer model for further calculation of the structure together with the ground one.

The capabilities of the programs are: forecasting movements and stresses; depiction of deformations and stresses in contour lines, vectors, isosurfaces and shades; depicting forces in cluster elements of volumetric cylindrical piles; constructing intersections and viewing the results in these intersections.







Afterword

"A building doesn't exist by itself — it depends on the environment and what's around it."

Paul Marvin Rudolph (1918–1997)