BUILDING CONSTRUCTIONS, BUILDINGS AND ENGINEERING STRUCTURES

СТРОИТЕЛЬНЫЕ КОНСТРУКЦИИ, ЗДАНИЯ И СООРУЖЕНИЯ

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Evaluating Building Operational Safety under Variations of the Technical Condition of Foundations

Vladimir I. Rimshin[1] ✉, **Alexandr S. Evdokimenko**[2], **Ekaterina S. Ketsko**[3], **Alexandr E. Vorobyev**[2], **Egor S. Savelyev**[2]
[1] National Research Moscow State University of Civil Engineering, Moscow, Russian Federation
[2] Novosibirsk State University of Architecture and Civil Engineering (Sibstrin), Novosibirsk, Russian Federation
[3] Research Institute of Building Physics of the Russian Academy of Architecture and Construction Sciences, Moscow, Russian Federation
✉ v.rimshin@niisf.ru

EDN: ENLSIC

Abstract

Introduction. Modern buildings operate under changing climate and loading conditions, where foundation degradation leads to cracks, uneven precipitation and load-bearing capacity loss. Regular monitoring and inspections enable timely risk detection, accident prevention and repair cost reduction. The aim of the study is to develop methods for assessing operational safety across various foundation conditions, including calculating precipitation and performance limits.

Materials and Methods. The study included visual inspection, structural scheme identification, instrumental diagnostics, building inspection with preparation of the architectural drawings, defect detection and documentation, installation of pits with preparation of measuring drawings of epy foundations for open pits and identification of the strength characteristics of the foundation material, opening structures and testing building materials to identify their strength characteristics with subsequent verification calculations of the load-bearing elements.

Research Results. Based on the results of the verification calculations and identified structural defects, the condition of the building elements and the building as a whole has been established. Recommendations have been developed for ensuring the normal operation of a building as well as for strengthening or repairing structures.

Discussion and Conclusion. Comprehensive technical inspection of the building using advanced non-destructive testing methods and verification calculations revealed the current technical condition of the foundation elements and foundations. Based on the results of the technical inspection, taking into account the results of the verification calculations, it can be concluded that for further normal operation of a building in some areas, it is necessary to take measures in order to strengthen the foundations or strengthen foundations soils. The scientific significance lies in the developed and testing of the methodology for comprehensive assessment of the load-bearing capacity of foundations taking into account real-world operating conditions, which makes it possible to increase the accuracy of forecasting the durability of buildings on weak soils. The practical value of the results lies in the formation of specific recommendations for strengthening foundations. The findings can be used in inspecting similar civil and industrial facilities.

Keywords: foundations, engineering and technical inspection, verification calculations, technical condition, deformation and strength characteristics

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Оригинальное эмпирическое исследование

Анализ эксплуатационной безопасности здания при вариациях технического состояния фундаментов

В.И. Римшин[1] ✉, А.С. Евдокименко[2], Е.С. Кецко[3], А.Е. Воробьев[2], Е.С. Савельев[2]

[1] Национальный исследовательский Московский государственный строительный университет, г. Москва, Российская Федерация

[2] Новосибирский государственный архитектурно-строительный университет (Сибстрин), г. Новосибирск, Российская Федерация

[3] Научно-исследовательский институт строительной физики Российской академии архитектуры и строительных наук, г. Москва, Российская Федерация

✉ v.rimshin@niisf.ru

Аннотация

Введение. Современные здания эксплуатируются в условиях изменяющегося климата и нагрузок, где изменения технического состояния фундаментов могут привести к трещинам, неравномерным осадкам и потере несущей способности. Регулярный мониторинг и обследование позволяют вовремя выявлять риски и предотвращать аварии, снижая затраты на ремонт. Целью исследования в данной статье является разработка методов оценки эксплуатационной безопасности при различных технических состояниях фундаментов здания, включая расчет осадок и пределов работоспособности.

Материалы и методы. Исследование включает в себя визуальный осмотр, определение конструктивной схемы здания, инструментальную диагностику, выполнение обмерных работ по зданию с составлением архитектурных чертежей, выявление и фиксацию дефектов, устройство шурфов с составлением обмерных чертежей фундаментов по отрытым шурфам и определение прочностных характеристик материала фундаментов, выполнение вскрытий конструкций и испытаний строительных материалов с определением их прочностных характеристик с последующим выполнением поверочных расчетов несущих элементов.

Результаты исследования. На основании результатов поверочных расчетов и выявленных дефектов по конструкциям устанавливалось состояние строительных элементов и здания в целом. Разработаны рекомендации для обеспечения нормальной эксплуатации здания и рекомендации по усилению или ремонту конструкций.

Обсуждение и заключение. Проведенное комплексное техническое обследование здания с применением современных методов неразрушающего контроля и поверочных расчетов позволило выявить текущее техническое состояние конструктивных элементов фундаментов и оснований. По результатам проведенного технического обследования с учетом результатов поверочных расчётов можно сделать вывод, что для дальнейшей нормальной эксплуатации здания на отдельных участках требуется выполнить мероприятия по усилению фундаментов или укреплению грунтов оснований. Научная значимость исследования заключается в разработке и апробации методики комплексной оценки несущей способности оснований и фундаментов с учетом реальных условий эксплуатации, что позволяет повысить точность прогноза долговечности зданий на слабых грунтах. Практическая ценность результатов состоит в формировании конкретных рекомендаций по усилению фундаментов. Полученные выводы могут быть использованы при обследовании аналогичных объектов гражданского и промышленного назначения.

Ключевые слова: фундаменты, инженерно-техническое обследование, поверочные расчёты, техническое состояние, деформационные и прочностные характеристики

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Introduction. Modern buildings are being operated in changing climatic conditions, dynamic loads and heterogeneous weak soils (bulk sands, water-saturated clays) leading to deformations of foundations, cracks, uneven precipitation and further to emergencies. The methods currently employed tend to focus on new structures, with no consideration of the operational characteristics of structures. The aim of the study is to develop a methodology for assessing the operational reliability of building foundations on various types of soils, calculating precipitation and identifying the technical condition of structures. To this end, the following tasks were set: to conduct an instrumental examination, perform verification calculations for Group I and Group II of limiting conditions, and to develop recommendations for strengthening foundations [1–4].

Materials and Methods. The work on the technical inspection of foundations and bases of a building included installing pits with preparing dimensional drawings of the foundations for the excavated pits and identifying the strength characteristics of the foundation material. The depth of the pits was identified taking into account the establishment of the actual depth of the existing foundations, their structures, strength of materials, etc. Soil samples were mostly taken in the range of 10–60 cm below the soles of the foundations of the undisturbed structure (3 samples for each pit), laboratory tests of the samples were performed based on the standard methods in compliance with the current state standards. The deformation and strength characteristics of the soils were identified according to Appendix B of SP 22.13330.2011 "Foundations of Buildings and Structures".

Based on the results obtained from the excavated pits, verification calculations of the bases of the foundations for Group II of limiting states (deformations) were performed. The calculations were conducted taking into account Clause 5.3.18 of SP 22.13330.2011.

While performing the verification calculations of the foundations, the following parameters were set: the calculated resistance of the foundations, permissible load on the foundations, pressure on the soles of the foundations considering the existing loads.

The inspection of vertical and horizontal load-bearing structures, staircases and roofs included a study of the condition of the load-bearing elements, including measurements with preparing architectural drawings of structural components at the excavation sites.

Defects were identified and photofixed in the interior of the building (in the areas of actual access) with preparing diagrams of the location of defects on the floor plans and fixing defects on the facades of the building with the application of defective areas on the sketch drawings of the facades.

Through the course of the technical inspection, the strength characteristics of building materials of load-bearing structures were identified by means of non-destructive testing methods. The concrete strength class was identified based on the direct measurements of concrete strength using non-destructive methods according to GOST 22690 "Concretes. Identifying the Strength by Means of Mechanical Methods of Non-Destructive Testing" (by means of the shock pulse method) and taking into account the requirements of Clause 8.3.5 of SP 13-102-2003 "Rules for Inspection of Load-Bearing Building Structures of Buildings" (the actual concrete strength class was set as $B = 0{,}8 \cdot R_{sc}$)[1,2] [1–3].

The strength characteristics of the reinforcement structures were identified based on an expert assessment considering the profile of the reinforcement, the year of construction of the building as well as the data of SNiP 2.03.01-84* "Concrete and Reinforced Cconcrete Structures". The calculated resistance of the rod reinforcement is assumed to be equal to R_s = 510 MPa, R_{sc} = 450 MPa — for fittings of the A600 periodic profile.

Tests of metal structures were not performed. The strength characteristics of rolled steel elements were identified according to SP 13-102-2003 and available reference data. While calculating the steel elements, the value of the calculated tensile strength of steel is assumed to be equal for columns made of rolled channels R_y = 230 MPa (for steel C235), for beams made of rolled I-beams, corner support tables and steel strips R_y = 240 MPa (for steel C245). For the calculation of welded joints, it is assumed that manual electric arc welding with E42 electrodes has been performed.

Based on the results of the excavations, measurements, and calculation of the strength characteristics of the materials, piecemeal verification calculations of horizontal and vertical load-bearing structures were performed.

Verification calculations of structures were performed according to Group I of limiting states (in terms of the load-bearing capacity) according to Section 10 of SP 13-102-2003. Verification calculations of steel structures were performed in compliance with SP 16.13330.2011 "Steel Structures", of reinforced concrete in compliance with SP 52-101-2003 "Concrete and Reinforced Concrete Structures without a Prestressing Reinforcement".

The verification calculations were performed considering the useful load for the ceiling above the 1st floor identified using SP 20.13330.2011 "Loads and Impacts" and amounting to 200 kg/m^2 (standard value). The useful snow load on the surfacing is assumed to be 180 kg/m^2 (snow region III). The standard load from the partitions is assumed to be 50 kg/m^2. The weight of the floors is 150 kg/m^2 (standard value). Since the roof was not opened, the load from the pie was assumed based on the expert assessment.

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[1] Bondarenko VM, Rimshin VI *Dissipative Theory of Force Resistance of Reinforced Concrete*. Moscow: Student; 2015. 111 p.
[2] Kurbatov VL, Rimshin VI, Dironas MV *Control and Supervision in Construction and Housing and Communal Services*. Mineralnye Vody; 2024.

While performing the verification calculations, the loads from the own weight of the structures were identified based on the excavations and measurements. The specific weight of the materials was identified based on the expert assessment: concrete γ_f = 24 kN/m^3; reinforced concrete γ_f = 25 kN/m^3; steel γ_f = 78,5 kN/m^3; bricks γ_f = 18 kN/m^3; claydite-concrete γ_f = 12 kN/m^3; cement-sand screed γ_f = 18 kN/m^3; backfilling soil γ_f = 16 kN/m^3.

Given the fact that selective excavations were performed, the load on the structures in some areas was identified based on the expert assessment. The forces in the structures were identified by means of the methods of structural mechanics. Based on the results of the verification calculations of the vertical and horizontal load-bearing structures, the following parameters were established: values of the actual load-bearing capacity of vertical and horizontal load-bearing structures, coefficient of utilization of the load-bearing capacity of the existing elements of vertical and horizontal load-bearing structures. The condition of the structures and the structure as a whole was identified based on the technical inspection and verification calculations. The inspection of the load-bearing structures, identification of the strength of the materials, and verification calculations were performed in compliance with the current regulatory documents [4–10].

The technical inspection of the building was performed in stages. Preliminary examination involved familiarization with the available documentation, general inspection of the facility, continuous visual inspection of the building structures, identification of defects and damage based on the external signs with a necessary measurements and fixation. A detailed continuous inspection involved performing measurements, measuring the strength characteristics of the materials of the load-bearing structures, performing openings of the load-bearing structures, setting up pits, performing measurement drawings of foundations and structures at the opening sites, performing engineering and geological inspections of the bases of foundations, designing measurement drawings of the floor plans, facades, sections, roof plan as well as the load-bearing layout schemes floor and coating structures, measuring the necessary geometric parameters of building structures, elements, nodes and foundations, instrumental identification of defect and damage parameters, performing verification calculations, analyzing the inspection results, writing a technical report with the conclusions based on the inspection results, preparing recommendations to ensure further normal operation of the building. The preliminary insoection included a preparatory period when the initial data was being collected and analyzed. Based on the preliminary inspection, the locations of the pits, openings and measurements of the strength characteristics of structures were established. The Onyx 2.6 device was used to identify the strength characteristics of the building materials by non-destructive methods. A total station inspection of the structures was performed by means of a Trimble M3 total station (5”)[3,4] [11–14].

Technical inspection of the building. A brief description of the inspection object

The administrative building under study was built in 1995 (two-storeyed, with no basement). The height of the rooms on the first floor from the floor level to the bottom of the floor slabs is about 3900 mm, the height of the second floor is about 2570 mm. The structural scheme of the building is a frame one. The structure is made in the form of two rectangular volumes with the overall dimensions of about 25.0×9.4 m and 37.2×9.8 m. The spatial rigidity and stability of the building is provided by the frame frames with rigid coupling of the columns with the foundations and hinged coupling of crossbars with the columns. The joint work of the frame elements is provided by rigid horizontal disks - prefabricated slabs of floor-to-ceiling and surfacing. The area around the building is planned, the courtyard is paved. An asphalt concrete blind area is made along the contour of the building. The drainage of meltwater and rainwater in an asphalt-paved area is provided by the vertical layout. The layout of the building is shown in Fig. 1.

The foundations for the frame columns are made of columnar monolithic reinforced concrete. The basement parts of the exterior walls are supported by monolithic reinforced concrete foundation beams laid on the column foundations. The wall panels of the aboveground part of the building above the basement are supported by solid concrete blocks via rolled steel elements (at the ground floor level), on the underlying panels (at the second floor level) and on steel support tables welded to the columns (at the first and second floor levels). The walls of the staircase block are supported by the concrete floors laid on the ground.

The main columns of the frame are made of composite cross-section of rolled steel channels No. 30, connected by strips of 200 ×7 mm with a pitch of about 700 mm. The main columns take the loads from the floors above the ground

[3] Rimshin VI, Bondarenko VM, Bakirov RO, Nazarenko VG *Reinforced Concrete and Stone Structures.* Moscow; Stroyizdat: 2007.
[4] *Inspection and Testing of Buildings and Structures.* Moscow; 2012.

floor and the coating, as well as from prefabricated expanded clay wall panels. Half-timbered steel columns made of paired channels No. 30 are arranged between the main columns of the frame. Half-timbered columns serve to support the exterior wall panels and withstand wind loads. There are no steel vertical connections along the frame columns.

The enclosing walls are made of prefabricated expanded clay wall panels 340 mm thick. The panels are made mainly of non-load-bearing (hinged) panels supported by steel support tables welded to the main columns of the frame and the half-timbered columns. The individual wall panels are self-supporting, supported by solid concrete blocks through steel linings made of rolled elements (at the ground floor level) and on the underlying panels (at the second floor level). The basement of the exterior walls is made of precast solid concrete blocks supported by monolithic reinforced concrete foundation beams. The facades are lined with brick about 120 mm thick. The facade cladding along the axes A, D and 9 is made of ceramic tiles in the form of factory wall panel cladding. The brickwork of the cladding is supported by prefabricated solid concrete blocks. The interior walls of the staircase block at the ground floor level are made of solid clay brick masonry on a cement-sand mortar. The wall thickness, including cladding, is about 310–460 mm. The partitions with a thickness of 90–410 mm are made of solid clay brick masonry, foam concrete blocks on cement-sand mortar and frame-sheathing of plasterboard sheets.

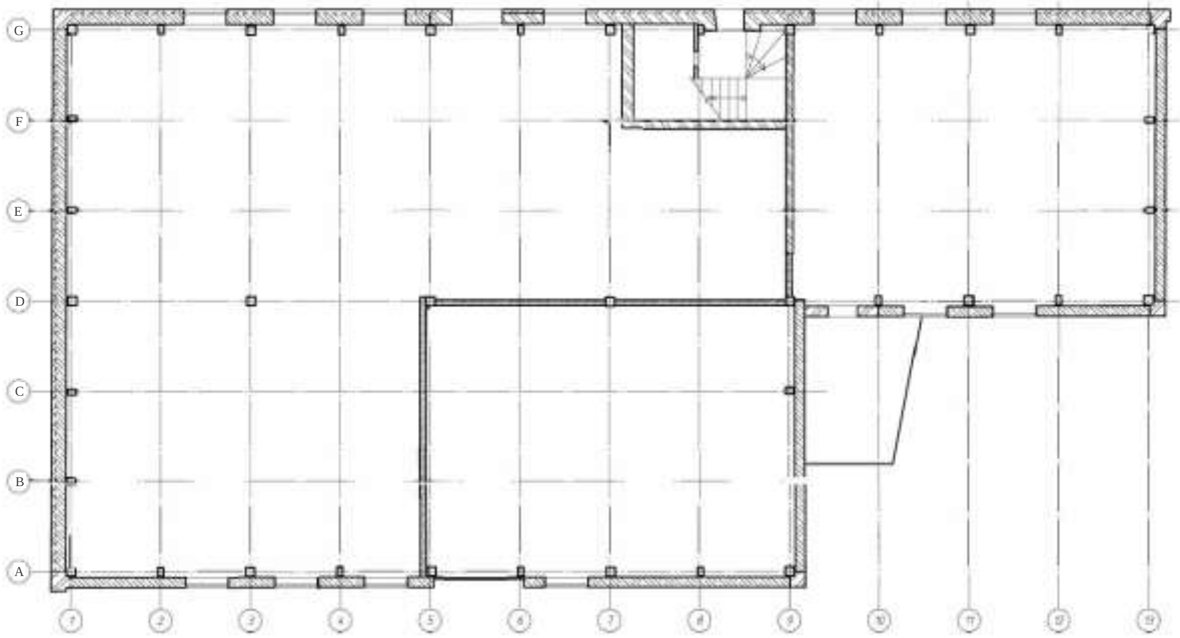

Fig. 1. Scheme of the building under study in the axes 1–13/A–G

The ceiling of the building is made according to a beam scheme of prefabricated reinforced concrete multi-hollow slabs measuring 6.0×1.2×0.22*(h)* m and 6.0×1.8×0.22*(h)* m supported by I-beam steel crossbars No. 50 and No. 50B2, as well as monolithic sections supported by reinforced concrete girders along axes A, G and 9–13.

Vertical communication throughout the building is provided by a two-marched prefabricated reinforced concrete staircase located in axes 7–9/F–G. The staircase from 0.000 m to +0.680 m is made of monolithic reinforced concrete. Safe movement along the staircase is ensured by fences made of steel elements.

The coating is made flat. Reinforced concrete multi-cavity slabs with a span of 6.0×1.2×0.22(*h*) m and 6.0×1.8×0.22(*h*) m are supported by steel crossbars of the I-beam frame No. 50 and No. 50B2, as well as monolithic sections supported by reinforced concrete girders with cross-sectional dimensions of 120×220(*h*) mm along axes A and G. Cross-section crossbars consisting of two rolling elements are united by steel bars.

Precipitation drainage is provided by sloping the roof surface in the direction of the funnels of the external downpipes. The roof is made of soft rolled material arranged on a layer of cement-sand screed and insulation. Along the contour of the roof there is a parapet made of solid clay bricks laid on a cement-sand mortar.

The exterior condition of the building is deemed satisfactory.

Results of the survey of bases and foundation soils. The column foundation along pit No. 1 in axes 9/A for the column is made in the form of a slab of monolithic reinforced concrete with overall dimensions of about 2.1×1.8×0.36(*h*) m. The coupling of the frame column with the foundation is provided by means of a column made of monolithic reinforced concrete measuring approximately 1×1×1.45(h) m. Reinforced concrete foundation beams with the overall dimensions of about 500×570 mm are arranged under the exterior walls. At the level of the top of the foundation beam, horizontal waterproofing is made from a layer of roofing material. The depth of the foundation from the level of the planned ground level is about d = 1.55 m. The layout of pit No. 1 and sections 1–1 and A–A are shown in Fig. 2.

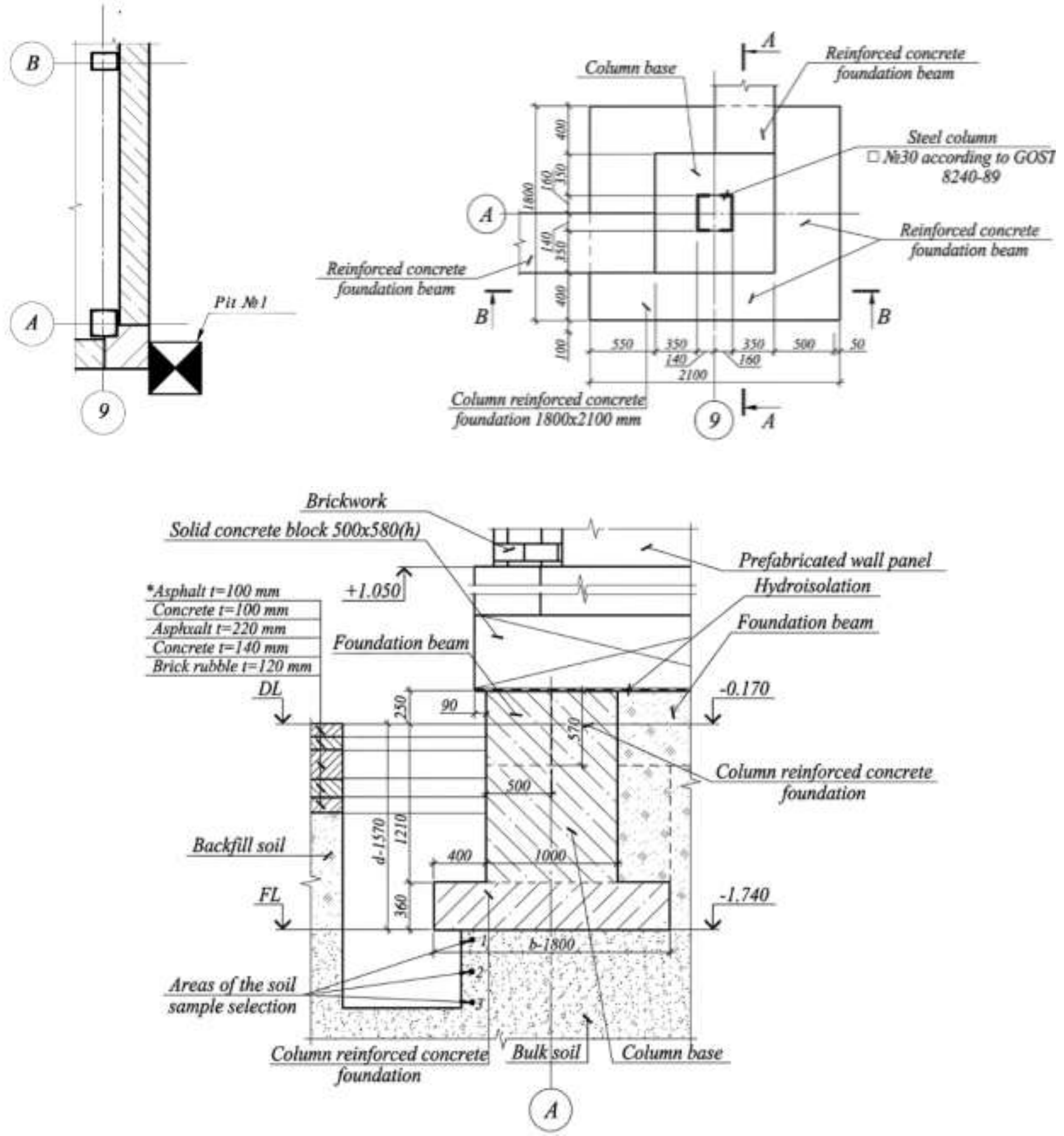

Fig. 2. Scheme of the layout of the pit No. 1 and section 1–1 and A–A

The column foundation along pit No. 2 in the 5/G axes for the column is made in the form of a slab of monolithic reinforced concrete with overall dimensions of about 2.4×2.4×0.6(h) m. The coupling of the frame column with the foundation is provided by means of a column made of monolithic reinforced concrete of 1.2×1.2×1.05(h) m. The depth of the foundation from the level of the planned ground level is about d = 2.65 m. Fig. 3 shows the layout of pit No. 2 and section A–A.

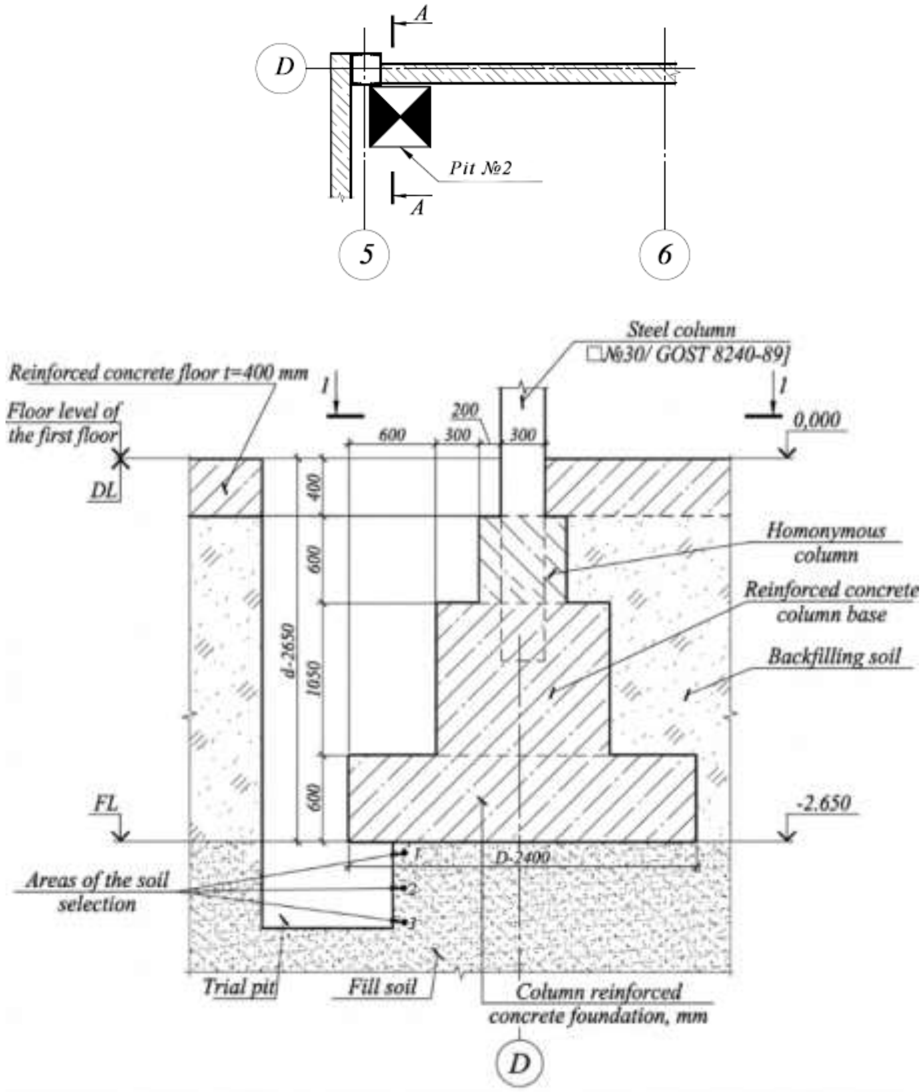

Fig. 3. Scheme of the layout of the pit No. 2 and section A–A

The columnar foundation along pit No. 3 in axes 1/H for the column is made in the form of a slab of monolithic reinforced concrete with overall dimensions of about 1.6×1.6×0.7(h) m. The conjugation of the frame column with the foundation is provided by means of a column made of monolithic reinforced concrete measuring 1.2×1.2×0.9(h) m. Reinforced concrete foundation beams with overall dimensions of about 500×570 mm are arranged under the exterior walls. At the level of the top of the foundation beam, horizontal waterproofing is made from a layer of roofing material. The depth of the foundation from the level of the planned ground level is about d = 1.6 m. In Fig. 4 shows the layout of pit No. 3 and section A–A.

The column foundation along pit No. 4 in axes 1/A for the column is made in the form of a slab of monolithic reinforced concrete with the overall dimensions of about 1.8×1.8×0.6(h) m. The coupling of the frame column with the foundation is provided by means of a column made of monolithic reinforced concrete measuring 1.0×1.0×1.0(h) m. Reinforced concrete foundation beams with the overall dimensions of about 500×570 mm are arranged under the exterior walls. At the level of the top of the foundation beam, horizontal waterproofing is made from a layer of roofing material. The depth of the foundation from the level of the planned ground level is about d = 2.0 m. Fig. 5 shows the layout of pit No. 4 and section A–A.

The foundation of the pit No. 5 in axes 7/F in sections A–A and B–B for the walls of the staircase block is made in the form of concrete floors on loose soil. The thickness of the floors is about 150 mm. There is no waterproofing of the floors. The depth of the foundation from the level of the planned ground level is about d = 1.05 m. Fig. 6 shows the layout of the pit No. 5 and section A–A.

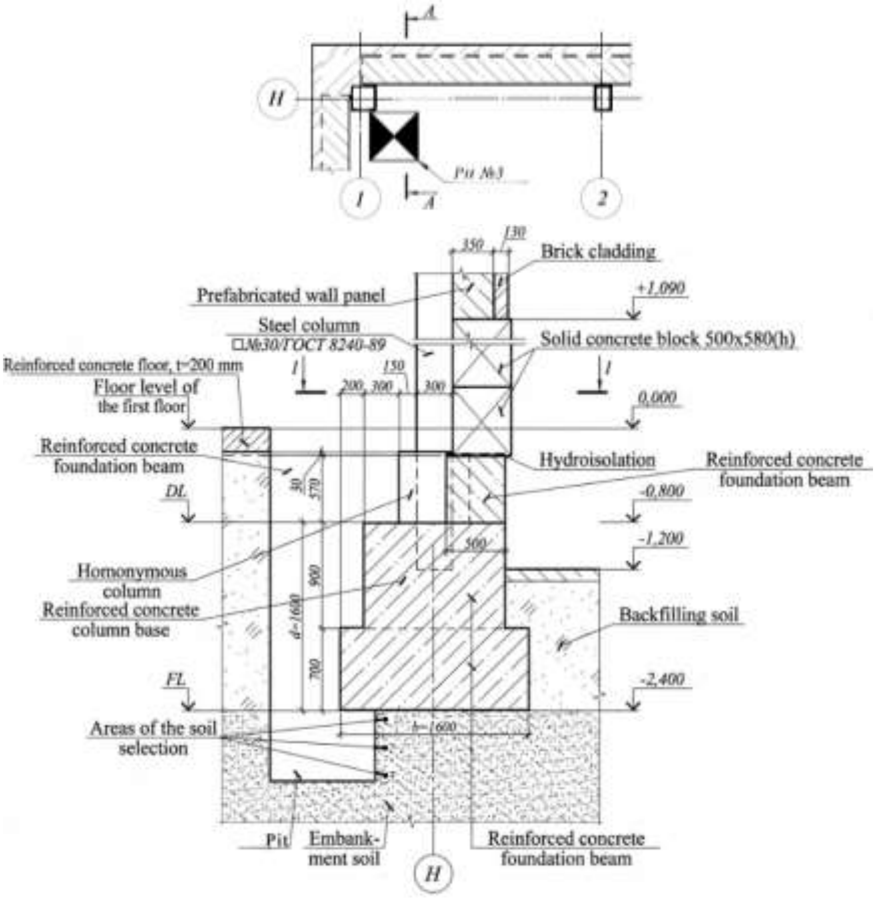

Fig. 4. Scheme of the layout of the pit No. 3 and section A–A

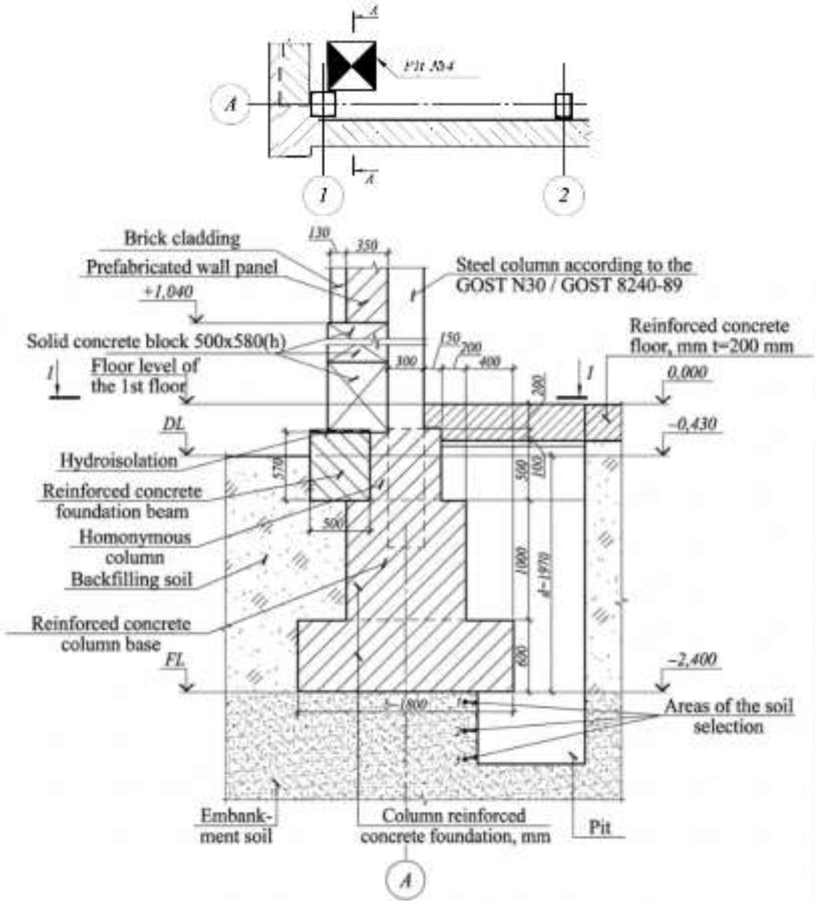

Fig. 5. Scheme of the layout of the pit No. 4 and section A–A

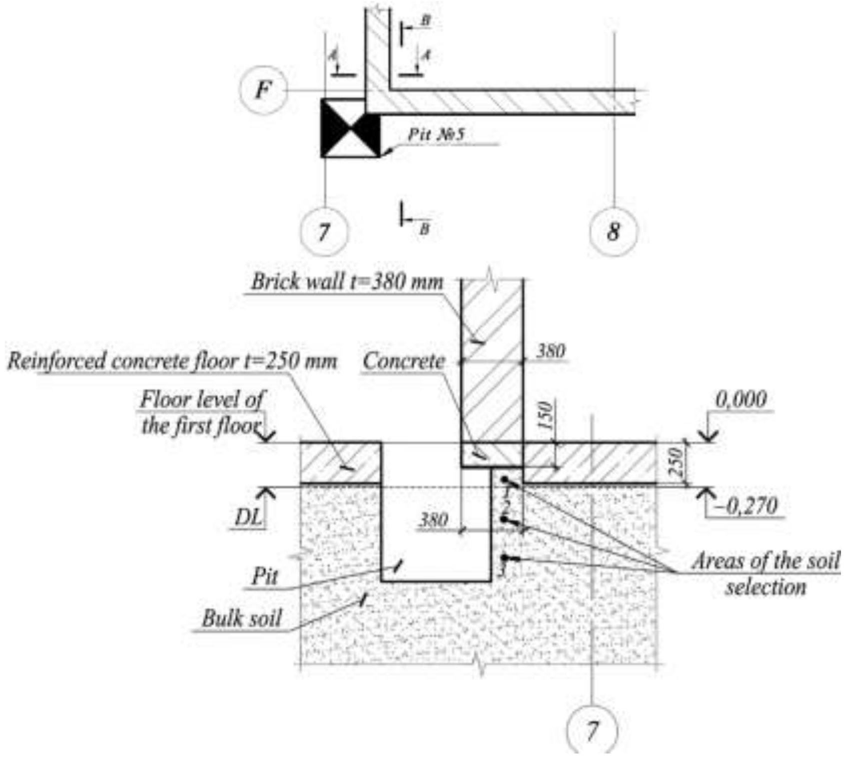

Fig. 6. Scheme of the layout of the pit No. 5 and section A–A

The column foundations for the columns of the frame and the foundation beams for the self-supporting exterior walls are made of monolithic reinforced concrete of a strength class of at least B20. The foundation for the walls of the staircase block is made in the form of concrete floors on the ground. The depth of the soles of the columnar foundations from the level of the planning mark is 1.05–2.65 m.

According to the opened pits No. 1, 3, 4, horizontal waterproofing is performed on top of the foundation beams from a layer of the roofing material. There is no waterproofing of the foundations and floors on the ground. The floors of the ground floor rooms are made of monolithic concrete 150–400 mm thick. No foundation defects have been identified. The concrete strength of columnar foundations and foundation beams, measured by means of non-destructive testing methods, corresponds to class B20 with a calculated compressive strength of R_b = 11.5 MPa.

In the pit No. 1 sandy bulk soils at a depth of 0.1–0.6 m from the base of the foundation have the following average values of the physical characteristics: soil density ρ = 18.8 kN/m^3; humidity w = 0.184; dry soil density ρ_d = 15.9 kN/m^3; soil particle density ρ_s = 26.7 kN/m^3; porosity coefficient e = 0.67; degree of water saturation S_r = 0.73. The granulometric composition is > 2 mm — 4.8%; > 0.5 mm — 8.2 %; > 0.25 mm — 24.7 %; > 0.1 mm — 46.7 %; < 0.1 mm — 15.6%. The underlying bulk soils are represented with high-quality dark gray-yellow fine sands of medium density, moist, clayey with inclusions of red brick crumbs, lime mortar and limestone rubble stone.

The minimum normative values of the strength and deformation characteristics of the underlying soils (according to Appendix B of SP 22.13330.2011) are as follows: specific adhesion a_s = 1 kPa; angle of internal friction φ_n = 31°; modulus of deformation E = 26 MPa.

While calculating the bases of the foundations for Group II of limiting conditions, the standard values of long-term loads were used. At the same time, for useful short-term loads on floors and from snow, long-term parts were taken by multiplying by reduction coefficients 0.35 and 0.7, respectively. While performing verification calculations of foundations, the calculated resistance of the bases of the foundations, the permissible load on the foundations, operating or design pressure on the soles of the foundations taking into account the accepted useful load were established [5,6,7] [15–21].

[5] *Technical Operation of Residential Buildings.* Moscow; 2012.
[6] Rimshin VI, Ketsko ES, Truntov PS *A Large Construction Dictionary. Volume 2 P–Ya.* Moscow: ASV; 2022. 626 p.
[7] Rimshin VI, Ketsko ES, Truntov PS *A Large Construction Dictionary. Volume 1 A–O.* Moscow: ASV; 2022. 572 p.

In the pit No. 1 in the 9/A axes with the overall dimensions of the columnar foundation about 2.1×1.8×0.36(h) m and a depth of about d = 1.55 m, the calculated resistance according to the minimum normative values of the strength characteristics of fine sands at a_s = 1 kPa and ϕ_n = 31° is R = 0.023 MPa. The collection of the loads on the foundation in the pit No. 1 is shown in Table 1.

Table 1

Collection of the loads. Pit No. 1

Loads	$A_{гр}$, m²	$q_{н}$, MPa	$q_{р}$, MPa	$N_{н}$, kN	$N_{р}$, kN
Loads from the surfacing					
Constant					
Weight of the surfacing and roofing	13.5	0.0056	0.0066	75.6	89.1
Temporary					
Surfacing	13.5	0.0009	0.0013	11.9	17.0
Loads from the ceiling above the 1st floor					
Constant					
Weight of the ceiling, floors	13.5	0.0052	0.0061	70.2	82.4
Temporary					
Temporary useful loads and partitions	13.5	0.0012	0.0015	16.2	20.8
Total loads on the foundation					
Weight of the ceiling				173.9	209.3
Weight of the walls and columns				256.6	294.9
Weight of the foundation				117.4	131.8
Total loads				547.9	636.0
Area of the sole of the column foundation, m²					3.78
Base pressure from the normative loads, MPa					0.15

Research Results. Based on the results of the verification calculations, the calculated resistance of the base soils is 0.23 MPa. The maximum permissible load on the foundation, taking into account a certain calculated resistance of the soil of the base and the dimensions of the foundation, should not be over 0.23 MPa. The average pressure at the base of the foundation, taking into account the accepted regulatory ceiling load of 2 kN/m^2, is about 0.145 MPa. The requirement of clause 5.6.7 JV 22.13330.2011 is met.

Similar verification calculations were performed for the pits No. 2–4. The calculation results are shown in Table 2.

Table 2

Results of the verification calculations for the pits

No. of a pit	R, MPa	N_{max}, MPa	p, MPa	Normative load, kN/m²	Compliance with Clause 5.6.7 SP 22.13330.2011
1	0.23	≤ 0.23	0.145	2	Is met
2	0.13	≤ 0.13	0.175	2	Is not met
3	0.18	≤ 0.18	0.188	2	Is not met
4	0.28	≤ 0.28	0.195	4	Is met

R is the calculated ground resistance of the foundation, Mpa; N_{max} is the maximum permissible load on the foundation taking into account the identified calculated ground resistance of the foundation and the dimensions of the foundation; p is the average pressure along the base of the foundation taking into account the accepted regulatory load on the floors, MPa.

In the pit No. 5 in axes 7/F (Section A–A), with a base width of about 0.38 m and a foundation depth of about d = 0.15 m (the wall rests on a concrete floor about 150 mm thick), the calculated resistance is equal to (in according to Table B.9 of SP 22.13330.2011) R_0 = 180 kPa (soil dumps with no compaction at a humidity level of no more than 0.5), is R = 0.09 MPa. In accordance with Table B.9 of SP 22.13330.2011, the calculated resistance of the underlying bulk soils for a conditional foundation with a sole width of 1.0 m and a depth of 2.0 m is R_0 = 180 kPa. The collection of the loads on the foundation in the pit No. 5 (section A–A) is shown in Table 3.

Table 3

Collection of the loads. Pit No. 5 (Section A–A)

Loads	$A_{гр}$, m²	$q_н$, MPa	$q_р$, MPa	$N_н$, kN	$N_р$, kN
Loads from the staircase structure					
Constant loads					
Weight of the staircase structure	2.8	0.0035	0.0039	9.8	10.8
Temporary loads					
Temporary useful	2.8	0.0011	0.0013	2.9	3.5
Total loads on the foundation, MPa					
Staircase structures				9.8	10.8
Weight of the wall				36.3	39.9
Weight of the foundation				1.4	1.6
Temporary useful				2.9	3.5
Total load				50.5	55.8
Width of the sole of the column foundation, m					0.38
Normative load pressure on the foundation, MPa					0.13

In the pit No. 5 in axes 7/F (Section B–B), with a base width of about 0.25 m and a foundation depth of about d = 0.15 m (the wall rests on a concrete floor about 150 mm thick), the calculated resistance is equal to (in according to Table B.9) R_0 = 180 kPa (soil dumps with no compaction at a humidity level of no more than 0.5), is R = 0.09 MPa. The collection of loads on the foundation in the pit No. 5 (section B–B) is shown in Table 4.

Based on the results of the verification calculations, the following has been established. In section A–A, the calculated resistance of the base soils is 0.09 MPa. The maximum permissible load on the foundation, taking into account a certain calculated resistance of the soil of the base and the dimensions of the foundation, should not be over 0.09 MPa. The average pressure at the base of the foundation, taking into account the accepted standard load on the staircase of 3 kN/m^2, is about 0.13 MPa. The requirement of Clause 5.6.7 SP 22.13330.2011 is not met.

Table 4

Collection of the loads. Pit No. 5 (Section B–B)

Loads	$N_н$, kN	$N_р$, kN
Weight of the wall	23.4	25.8
Weight of the foundation	0.9	1.0
Total load	24.3	26.8
Width of the sole of the column foundation, m		0.25
Normative load pressure on the foundation, MPa		0.0975

In section B–B, the calculated resistance of the base soils is 0.09 MPa. The maximum permissible load on the foundation, taking into account a certain calculated resistance of the soil of the base and the dimensions of the foundation, should not be over 0.09 MPa. The average pressure at the base of the foundation is about 0.1 MPa. The requirement of Clause 5.6.7 SP 22.13330.2011 is not met.

As there are loose soils with a low design resistance (below the design pressure) in certain sections of the building at the base of the foundations, the condition of the foundations for the columns of the frame and the walls of the staircase block is characterized as unsatisfactory — Category III (limited operability). According to the results of the technical inspection, given the results of the verification calculations (Table 5) it can be concluded that for the further normal operation of the building in some areas, it is necessary to take measures in order to strengthen the foundations or the bases of the foundations.

Table 5

Results of the verification calculations of the soils of the foundations and structures of the foundations

Location of the foundation	Load-bearing capacity of the foundation structures based on the material, MPa	Design resistance of the foundation soils, MPa	Permissible load on the foundation soils, MPa	Existing load on the foundation, MPa	Coefficient of the use for the soil	Coefficient of the use for the foundation structures
Column foundation in the pit No. 1 in the axes 9/A	Determined by the reinforcement of the structures	0.23	0.23	0.145	0.63	Determined by the foundation soil
Column foundation in the pit No. 2 in the axes 5/D	Determined by the reinforcement of the structures	0.13	0.13	0.175	1.35	Determined by the foundation soil
Column foundation in the pit No. 3 in the axes 1/Zh	Determined by the reinforcement of the structures	0.18	0.18	0.188	1.04	Determined by the foundation soil
Column foundation in the pit No. 4 in the axes 1/A	Determined by the reinforcement of the structures	0.28	0.28	0.195	0.7	Determined by the foundation soil
Ribbon foundation in the pit No. 5 in the axes 7/E (Section A–A)	1.5	0.09	0.09	0.133	1.48	0.1
Ribbon foundation in hte pit No. 5 in the axes 7/E (Section B–B)	1.5	0.09	0.09	0.1	1.09	0.07

Discussion and Conclusion. A comprehensive technical inspection of the building by means of modern methods of non-destructive testing and verification calculations has revealed the current technical condition of the structural elements and foundations.

Based on the results of the technical inspection, it can be concluded that the condition of the building is deemed satisfactory — Category II (operational), except the foundations under the columns of the frame and the walls of the staircase block, with its condition characterized as unsatisfactory — Category III (limited operational).

It has been found that in order to ensure the normal operation of the building in areas with bulk soils (pits No. 2, No. 3, No. 5), it is necessary to take measures to strengthen the foundations or bases. Ribbon foundations for the walls of a staircase block can be reinforced by means of widening the sole or strengthening the foundations of the bases, column foundations for columns — by means of installing a column foundation or strengthening the foundations of the bases. It is recommended that the base of the foundations of the walls of the staircase block is widened by means of installing a monolithic reinforced concrete cage (at least 300 mm wide) or a liner. The final overall dimensions of reinforcement structures should be identified by means of calculations. The pile base for the frame columns can be made of vertical drilling piles. A joint operation of piles and foundation structures should be ensured by tying the reinforcing frames of piles with foundation structures and their subsequent concreting. Base soils can be strengthened by injecting cement or special mortars into the soil.

The above method of comprehensive assessment of operational safety in various technical conditions of building foundations increases the forecast of operability, load-bearing capacity and durability and is applicable to similar structures.

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About the Authors:

Vladimir I. Rimshin, D.Sc. (Eng.), Professor, Professor of the Department of Housing and Communal Services at the National Research Moscow State University of Civil Engineering (26 Yaroslavskoye Highway, Moscow, 129337, Russian Federation), Head of the Laboratory for Monitoring Housing and Communal Services and Radiation Safety in Construction at the Scientific Research Institute of Building Physics of the Russian Academy of Architecture and Building Sciences (21 Locomotive Passage, Moscow, 127238, Russian Federation), ScopusID, ORCID, v.rimshin@niisf.ru

Alexandr S. Evdokimenko, Cand.Sci. (Economics), Associate Professor of the Department of Economics, Management, Sociology and Pedagogy, Novosibirsk State University of Architecture and Civil Engineering (Sibstrin) (113 Leningradskaya Str., Novosibirsk, 630008, Russian Federation), ORCID, as@sibstrin.ru

Ekaterina S. Ketsko, Postgraduate Student at the Scientific Research Institute of Building Physics of the Russian Academy of Architecture and Building Sciences (21 Locomotive Passage, Moscow, 127238, Russian Federation), ORCID, kkuzzina@mail.ru

Alexandr E. Vorobyev, Student of Novosibirsk State University of Architecture and Civil Engineering (Sibstrin) (113 Leningradskaya Str., Novosibirsk, 630008, Russian Federation), ORCID, a.vorobyev@sibstrin.ru

Egor S. Savelyev, Student of Novosibirsk State University of Architecture and Civil Engineering (Sibstrin) (113 Leningradskaya Str., Novosibirsk, 630008, Russian Federation), ORCID, e.savelyev@sibstrin.ru

Claimed contributorship:

VI Rimshin: scientific supervision, formation of the basic concept, aims and objectives of the research, methodological expertise, review of all versions of the manuscript, approval of the results and conclusions, approval of the final version for publication.

AS Evdokimenko: development of the research concept, analysis of the research results, revision of the manuscript, correction of the conclusions.

ES Ketsko: preparation of the research materials, collection and verification of the data, formation and editing of the final version of the manuscript.

AE Vorobyev: collection of the data, processing of the results, design of the tables.

ES Savelyev: collection of the data, processing of the results, preparation of the references.

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All authors have read and approved the final version of manuscript.

Об авторах:

Римшин Владимир Иванович, доктор технических наук, профессор, профессор кафедры жилищно-коммунального комплекса Национального исследовательского Московского государственного строительного университета (129337, Российская Федерация, г. Москва, Ярославское шоссе, 26), заведующий лабораторией мониторинга жилищно-коммунального хозяйства и радиационной безопасности в строительстве Научно-исследовательского института строительной физики Российской академии архитектуры и строительных наук (127238, Российская Федерация, г. Москва, Локомотивный проезд, 21), ScopusID, ORCID, v.rimshin@niisf.ru

Евдокименко Александр Сергеевич, кандидат экономических наук, доцент кафедры экономики, управления, социологии и педагогики, Новосибирского государственного архитектурно-строительного университета (Сибстрин) (630008, Российская Федерация, г. Новосибирск, ул. Ленинградская, 113), ORCID, as@sibstrin.ru

Кецко Екатерина Сергеевна, аспирант Научно-исследовательского института строительной физики Российской академии архитектуры и строительных наук (127238, Российская Федерация, г. Москва, Локомотивный проезд, 21), ORCID, kkuzzina@mail.ru

Воробьев Александр Евгеньевич, студент Новосибирского государственного архитектурно-строительного университета (Сибстрин) (630008, Российская Федерация, г. Новосибирск, ул. Ленинградская, 113), ORCID, a.vorobyev@sibstrin.ru

Савельев Егор Сергеевич, студент Новосибирского государственного архитектурно-строительного университета (Сибстрин) (630008, Российская Федерация, г. Новосибирск, ул. Ленинградская, 113), ORCID, e.savelyev@sibstrin.ru

Заявленный вклад соавторов:

В.И. Римшин: научное руководство, формирование основной концепции, целей и задач исследования, методологическая экспертиза, рецензирование всех версий рукописи, утверждение результатов и выводов, утверждение финальной версии для публикации.

А.С. Евдокименко: разработка концепции исследования, анализ результатов исследований, доработка текста, корректировка выводов.

Е.С. Кецко: подготовка материалов исследования, сбор и верификация данных, формирование и редактирование финальной версии рукописи.

А.Е. Воробьев: сбор данных, обработка результатов, создание таблиц.

Е.С. Савельев: сбор данных, обработка результатов, подготовка литературы.

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