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DRILL INJECTED TECHNOLOGY APPLICATION EXPERIENCE FOR THE PURPOSE OF GROUND REINFORCEMENT AND PILE ERECTION DURING RECONSTRUCTION

The drill injected technology for pile erection and shallow foundations strengthening implementation in practice is described in the article. The reconstruction of the building, the topography and geotechnical conditions of the building footprint analysis are presented. The article reveals the design solutions for reconstruction of existing building for industrial purposes, and describes the basic technological processes. It is considered design scheme of the building, the results of the spatial frame calculation, the substantiation of bases slab base strengthening necessity provided design solutions for building new above-ground building structures. The article describes the case of pile foundations for the elevator shaft building, the description of the technical solutions in piling, the results of piled-raft foundation settlement observations, which was loaded by the loads from the walls and ceilings of mine and lifting equipment. The paper discloses the design of technical solution for existing slab base of special technology foundation strengthening, the technology of amplification, as well as the results of experimental and control sensing.

***Keywords**: injection, settlement, foundation, pile, test, observation, the raft.*

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ДОСВІД ЗАСТОСУВАННЯ БУРОІН'ЄКЦІЙНОЇ ТЕХНОЛОГІЇ ДЛЯ ПОСИЛЕННЯ ОСНОВ ТА ВЛАШТУВАННЯ ПАЛЬ ПРИ РЕКОНСТРУКЦІЇ

Досліджено питання впровадження в практику будівництва буроін'єкційної технології для влаштування паль і посилення основ фундаментів мілкого закладення. Наведено опис будівлі, що реконструюється, аналіз рельєфу й інженерно-геологічних умов площі забудови. Розкрито проектні рішення з реконструкції існуючої будівлі для виробничих потреб, описано основні технологічні процеси. Розглянуто розрахункові схеми будівлі, результати об'ємного просторового розрахунку каркаса, наведено обґрунтування необхідності посилення основи плитних фундаментів, проектні рішення щодо вбудування нових надземних будівельних конструкцій. Обґрунтовано влаштування пальових фундаментів для вбудованої ліфтової шахти, дано опис технічних рішень з улаштування паль, наведено результати спостережень за осіданням пальово-плитного фундаменту, що завантажений стінами і перекриттям шахти та ліфтового обладнання. Наведено проектні технічні рішення з підсилення основ існуючих плитних фундаментів буроін'єкційною технологією, технологією посилення, а також результати контрольного зондування.

***Ключові слова**: ін'єкція, осідання, основа, паля, спостереження, ростверк.*

Introduction. There is a large number of unfinished construction of buildings and structures, industrial and residential purpose in the Republic of Belarus. These buildings are not being exploited, physically and morally obsolete nowadays. The new investors that come on the market in our country, repurchase such buildings, perform their reconstruction and introduce them into service. In one of these renovation projects it is involved
the arrangement of a new floor, the device of the elevator shaft was used for the application of special technologies.

Building footprint topography and geological analysis. The building was built on the planned site, the area is confined to the fluvioglacial plain within Minsk hills. The primary relief of the building footprint of the building was changed during the construction of adjoining buildings, roads, laying of city communications, landscaping. Adjacent to the building territory is not landscaped, grass is missing partially.

As a result of the 2015 survey, it was identified that the geological structure to a depth of 15.0 m from the level of planning involved the following deposits (top – down):

A) modern anthropogenic (artificial) deposits of the Holocene horizon (thIV), represented by different grain size of sand heaps, from clay sand with inclusions of 10-15% of the gravel, pebbles and construction waste (broken bricks, concrete rubble, glass, wire). Opened the maximum capacity of 3.9 m Prescription fills for over 15 years. Bulk soil lies above the depth of the foundations, is characterized by heterogeneity of composition, addition and compressibility.

B) deposits Ajskogo horizon (g II sz)

– fluvioglacial nadmiernie (fIIsžs) deposits, represented by Sands of medium, coarse and gravelly yellow, brownish-yellow, malovlazhnyh, buried under loose soil with the opening capacity of 4.4 and 6.4 m.

– moraine (gIIsž) deposits are represented by sandy loam red-brown solid, with the inclusion of gravel and pebbles up to 15%, with frequent layers of sand up to 10 cm, overlain by fluvioglacial Sands with depths of 7.6 and 10.0 m.

Soil characteristics are given in table 1.

Table 1 – Soil characteristics

	Name of soil	Humidity	Density, кН/m^3			Cohesion, кPa			Angle of friction, degree			Deformation modulus. MPa	p_d MPa
		w	$\gamma_н$	γ_{II}	γ_I	$c_н$	c_{II}	c_I	$\varphi_н$	φ_{II}	φ_I	E	
	Anthropogenic (artificial) deposits of the Holocene horizon (thIV)												
1	Made ground	12,4	18,7	18,3	18,0								2,0
	Fluvioglacial nadmiernie (fIIsžs) deposits												
2	Sand medium strength	4,3	17,4	17,4	17,4	1,4	1,4	9	36	36	33	29	7,6
3	Sand large and gravelly	6,2	15,6	15,6	15,6	-	-	-	34	34	31	12	1,5
4	Sand large and gravelly medium strength (2,8 ≤ Pd, МПа ≤ 6,0)	5,7	16,8	16,8	16,8	0,3	0,3	0,2	37	37	34	20	4,2
5	Sand large and gravelly (6,0 <Pd, МПа ≤ 14,0)	5,1	17,7	17,7	17,7	0,7	0,7	0,5	39	39	35	35	8,6
	Moraine (gIIsž) deposits												
6	Sandy loam	8,7	21,8	21,7	21,7	36	36	24	28	28	24	25	6,0

The area is characterized by the absence of groundwater in the hydrogeological respect.

Overview of existing object. The frame of the building was built in 1990, in the 1990 to 2014, no construction work in the building was conducted. Building is multi-storied, rectangular in plan, with dimensions for the outer axes 111,325×21,245 m, the level of responsibility – II (normal), the complexity class of the building according to STB 2331-2014 K3. Engineering networks of water supply, sanitation, electricity to the building before the renovation was summed up.

The building consists of two main blocks structurally:

– multi-storey block (in the axes 1-11) was made with slab foundations on a natural basis in full frame with load-bearing structures of reinforced concrete prefabricated elements with self-supporting enclosing brick walls of the stairwell and wall claydite-concrete panels.

– 2nd administrative block B, located in the axes 12-20 – frameless, four-storey, including basement, done with the bearing longitudinal reinforced concrete walls in the basement and brick walls on 1-3-rd floor; ceilings and floors of precast concrete slabs.

The roof of the building is combined, roll with organized internal drain.

The results of the survey, based on [2,] showed that building structures have common critical defects.

Design solutions. The new owner desicion was to design project documentation for the reconstruction of the existing building into a multifunctional centre for social and industrial purposes.

The reconstruction is provided by stages. At the 1st stage the project envisages reconstruction of block A (in the axes 1-11) for the production designation aim, and the bringing in of external engineering networks; vertical planning of the territory, construction of new transformer substations, landscaping of the production site. At the 2nd phase of reconstruction of housing social purpose the Customer has decided to make reconstruction of the production part of the building to contain the printing company (according to [3]) with the capacity of 5000000 liters/month (for labelling products, cartons, booklets, catalogues, magazines, calendars of various kinds, promotional products, posters, books, brochures) at this stage.

The printing plant consists of the main parts for production purposes (typography in axes 3-11/B-E) and the administrative part in axes 1-3/B. Reconstruction of the production, made according to [6], unit involves the division of the 2nd floor in two. New recessed floors are devoted for administrative office needs. Design value of uniformly distributed regulatory burden on the 1st floor in industrial premises and 20 kPa, on the 2nd floor – 13 kPa, on the 3rd – 2,0 kPa.

Design solutions implementation. The following major works were completed while building:

1) a brick elevator shaft for a 3.2 tons capacity elevator was built in the axes 2-3/D-E. The Elevator shaft has a pit and machine room, protruding above the roof. The foundations of the lift shaft – pile [made according to 5, 8], CFA piles united on top by a monolithic reinforced concrete grillage. The walls of the Elevator shaft is designed and made of solid ceramic bricks. The ceiling of the engine room and covering – reinforced concrete castorbridge on steel beams;

2) the existing concrete slabs strengthening was made at elevation +6,000 for design regulatory load 13 kPa;

3) the new monolithic reinforced concrete slab on steel beams in the axes 5-11/B-E at around 10,400 and in axes 1-2/b-E at around +3,000 were erected.

4) the slab foundation basement was strengthened by the injection molding.

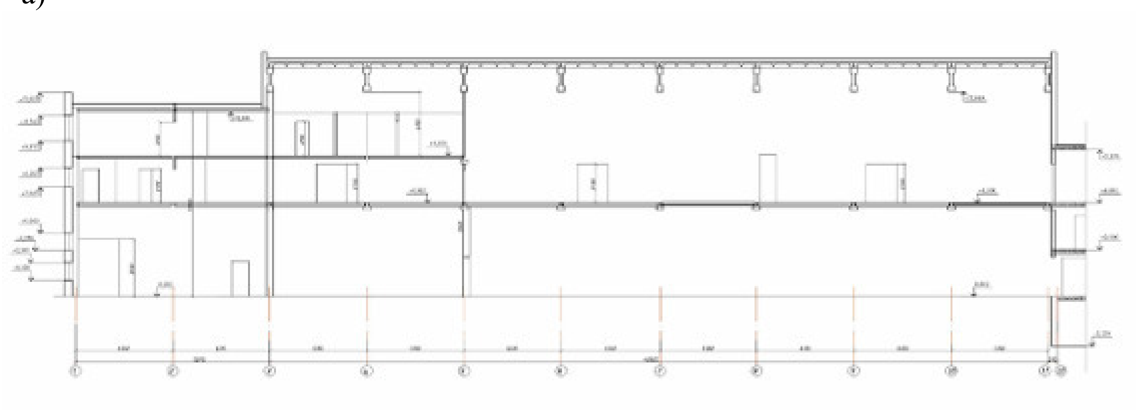
Volumetric building frame calculation. To determine the correct force arising from existing building structures it was determine the required elements and types of amplification, was determined deformations and precipitation was performed volume calculation of the whole building block.

Static calculation of a building frame in two groups of limit states was performed on the software package SOFiSTiK. The estimated complex implements finite element modeling of static and dynamic design diagrams, checking of stability, the choice of disadvantageous combination of efforts, selection of reinforcement for reinforced concrete structures, verification of the bearing capacity of steel structures in accordance with the applicable rules of structural engineering of the Republic of Belarus.

The calculation considered the spatial work of building structures. The estimated model includes only load-bearing elements of the building: columns, tie, wheels and floor coverings. Columns, braces and joists present the core elements of the General type. Plates of overlappings and coverings were presented by the bending flat final elements that have node six standard degrees of freedom (3 linear and 3 rotational) and are able to withstand longitudinal and lateral forces, bending moments.

It was considered all permanent and short-term loads and impacts that correspond to its functional purpose and constructive solutions when performing the calculations.

a)



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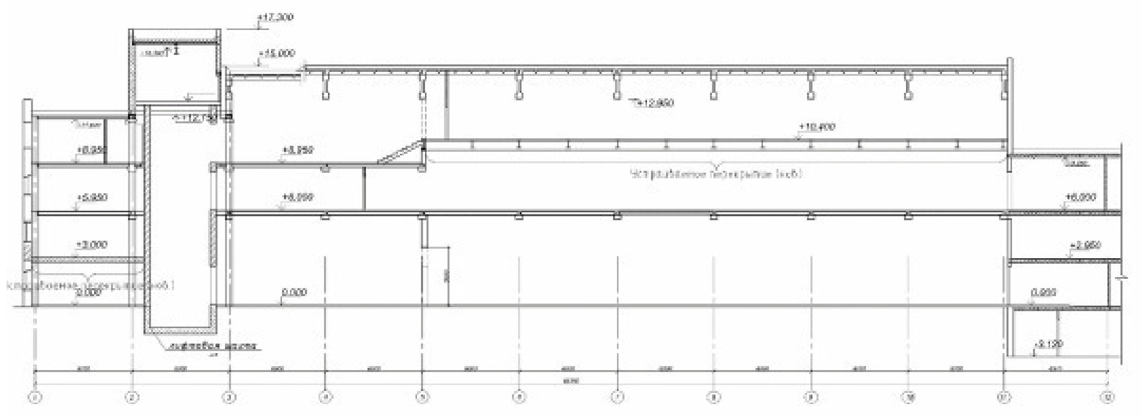


Figure 1 – Building scheme
a – existing building, b – design solutions

The calculation results. The spatial frame of the building performed calculation proofed the need of the existing building structures and grounds reinforcement: the maximum relative difference between the sediment foundations without reinforcement made up 27/6000 = 0,0045, and exceed the maximum normalized value ΔS/L = 0,002, in the design scheme have been adjusted with respect to the strengthening of injection foundation methods, which reduced the value of the maximum precipitation is the foundation of the middle column with 54 mm to 34 mm, and thus the maximum relative difference between residue of the foundations amounted to 8/6000 = 0,0001.

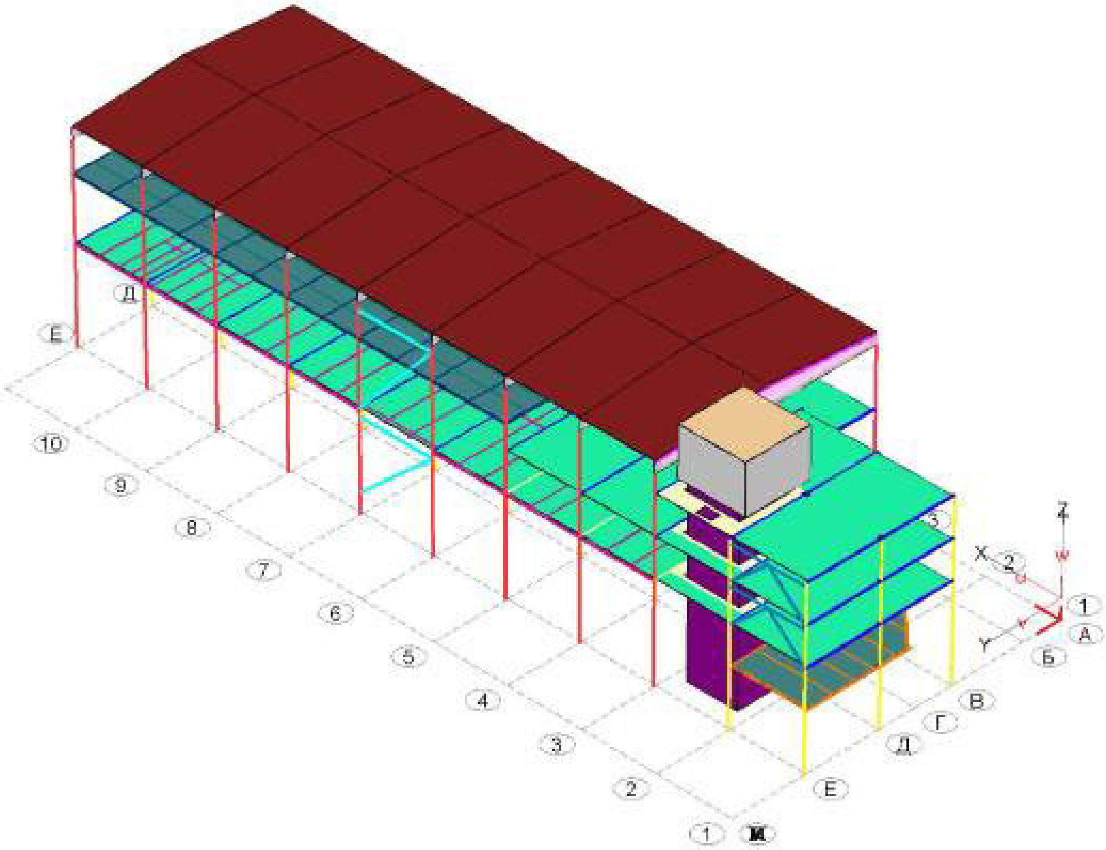


Figure 2 – Building calculation model

The elevator shaft device. The connection between the 1st and 2nd floors is provided be the 3.2 tons capacity elevator, which is situated in the axles 2-3/ B-D. The building frame column foundations are located near the mine being built – slab, monolithic with the size of the midsole in terms of 2.28...2,40×1,80 m and a depth from the floor level – a...3,540 3,710. Due to the presence of a sufficiently large capacity of bulk soils and also near located framework columns shallow foundations, in was made a decision to erect the device pile foundation under the elevator shaft [4, 5, 10].

Due to the cramped conditions of construction, his tight schedule, and testing research on influence of injection molding on the bearing capacity and deformability of foundations pile foundations it was decided to perform the loading experienced piles loads from building constructions erected an Elevator shaft with the observation of rainfall system, «Bush pile - raft Foundation». After pouring of pile caps it was found only 7 brands which according to [1] and was determined by precipitation (Fig. 3). Precipitation amount was measured in a specially designed program with step size of 0.1 N, where N is the design force on the raft. The latest measurement of the sediment was performed after all construction works and commissioning of elevators with its test.

Figure 3c shows that the measured value of the residue does not exceed the maximum values imposed [1] to the piles experienced strain.

The results of the experimental investigations established that wall of the concrete sump is a raft perceiving impact of the Elevator shaft building and transmitting it to the pile. However, precipitation is experienced marks located on the pit walls that are more important than sediment in the Central part (Fiig. 3). This is because at the center of the raft bottom directly above the Central piles brand No. 7 were installed and it can be concluded that the rigidity of a raft monolithic slab foundation are not completely evenly distributes impact loads.

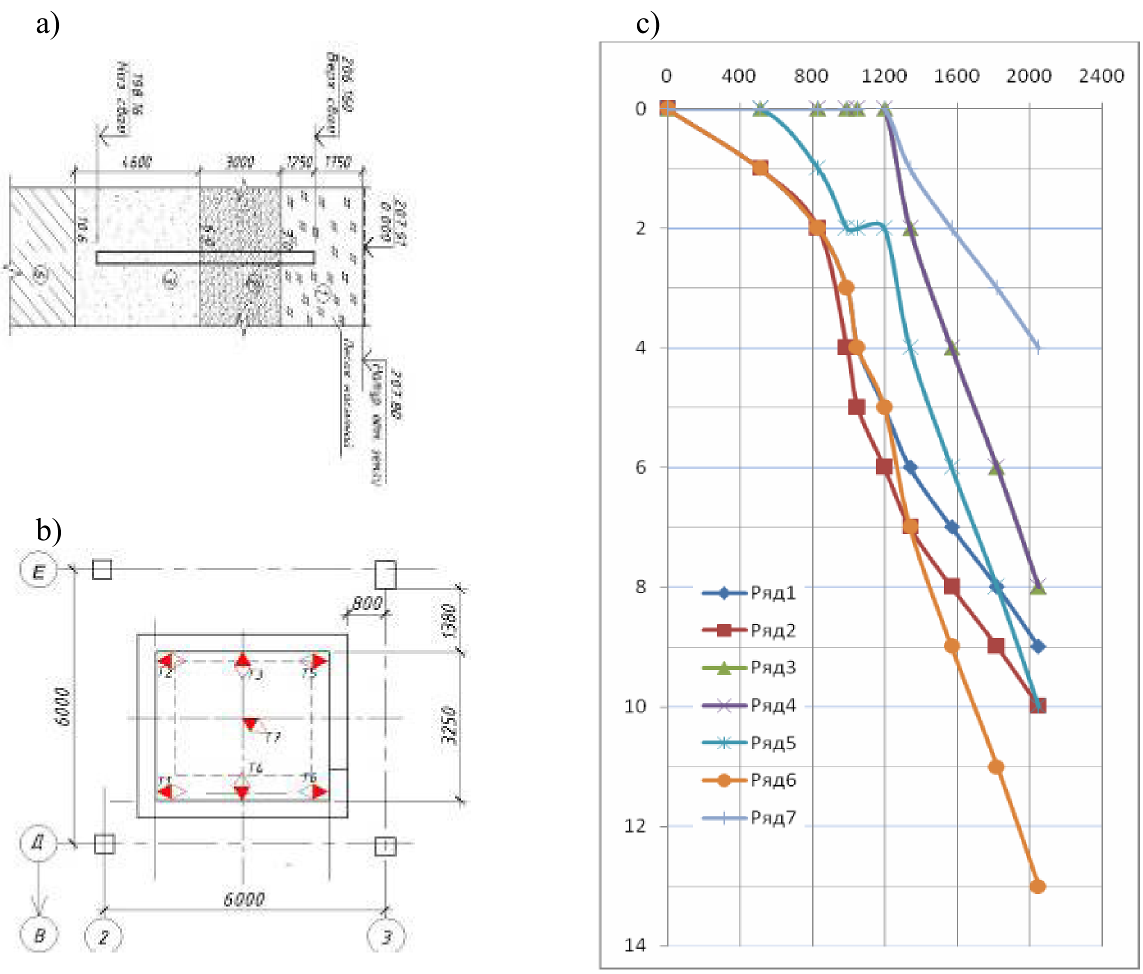


Figure 3 – layout of experienced brands
a – geological column with applied pile; b – layout of an experienced brands (1-7);
c – experienced brands settlements

Strengthening foundations for the perception of new loads. The foundations of interior columns along the axis B/4-10 – slab, monolithic with the size of the midsole in terms of 1,7...1,8×1,6...1.7 m, and the depth from the floor level is 3.1...3.2 m. The columns of the building are rigidly embedded in monolithic glasses. The base of the foundation is sand of medium strength (EGE – 2), a layer thickness of 1.8 m, underlain by coarse Sand large and gravelly medium strength (EGE-4), either directly the large sand gravelly medium strength (EGE-4).

It was decided according to [9, 10] to perform applying drillinjected technology for the base strengthening.

Injection strengthening of foundations are performed in the following sequence:

– 1 drilling under the protection of casing pipes with a diameter of 133 mm to the design level with the help of compact drilling machine;

– 2 in the well it was lowered two injector where the lower ends were closed with plugs;

– 3-hole on top filled with dry sand medium with simultaneous extraction of the casing after the wellhead was cement-sand mortar to a depth of 0.3 m;

– 4 after curing the cement-sand mortar was produced by the injection of cement mortar W/C = 0.45 initially, after a short injection tube T2 (60L), and then through a long (70hp); The fix solution was made smoothly, gradually increasing the pressure to value not more than 0.3 MPa for the short injector, and not more than 0.8 MPa, for long the injector. The speed of the set pressure should be 0.1 MPa per minute. Water solution for injection was prepared with a/C=0,45 for the Portland cement grade not lower than 400 with careful mixing each batch for at least 10 minutes prior to pumping in order to facilitate trade and to reduce the ability to sedimentation;

– 5 after performing the injection amplification in accordance with [8] to assess the variability of soil properties and efficiency of gain slab base it was made soils dynamic sensing. The results of the tests are discussed later.

a) b)

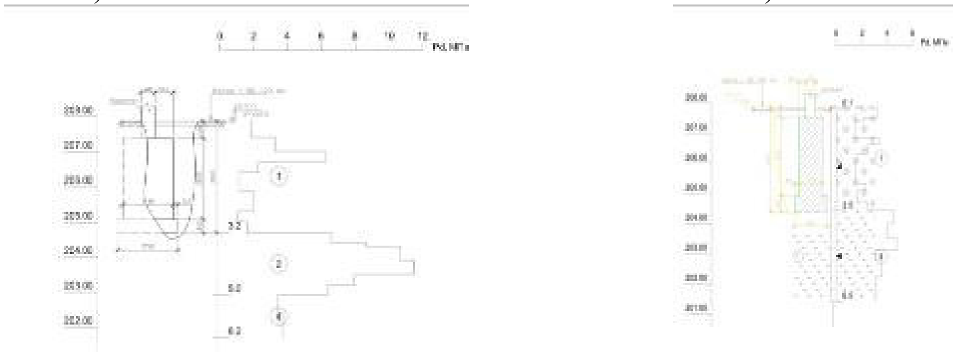
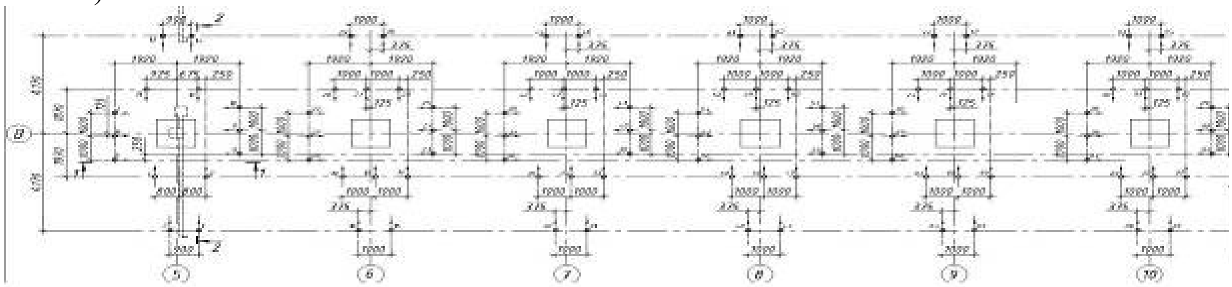


Figure 4 – Geological column with applied foundations.

a)



b) c)

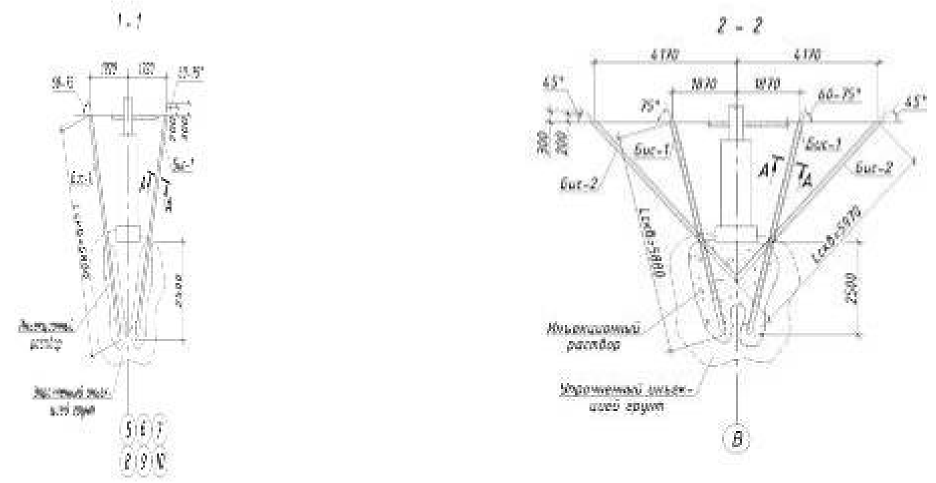


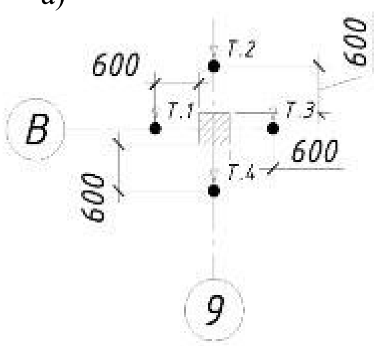
Figure 5 – Design solutions for the strengthening of the foundation bases
a – the scheme of location of injection wells; b – strengthening along the section 1-1;
c – strengthening along the section 2-2

Determining the quality of injection molding. The purpose of injection molding quality control was to check soils bearing capacity after grouting reinforcement. Dynamic sensing of exposed soils located in the area of the columns Nos. 5, 9. It was performed seven trials. The tests were carried out with a probe driven in accordance with STB 1241-2000.

Graphs of the dynamic resistance of the soil sensing and modifying the strength characteristics of silty sand and medium sandy loam according to the results of the performed works are presented on the figure (it should be noted that the graphs of the dynamic sensing give the similarity streaming chart of the static sensing for better visualization of obtained results).

As a result, at the probing set, it was found out that hardened injection solutions thick soils are located in depths of three feet.

a)



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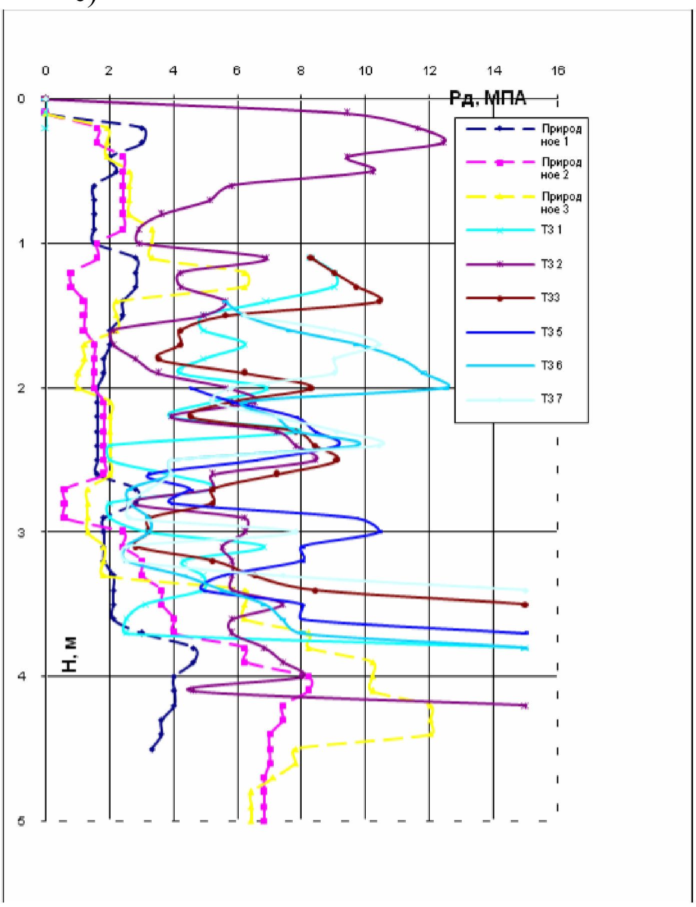

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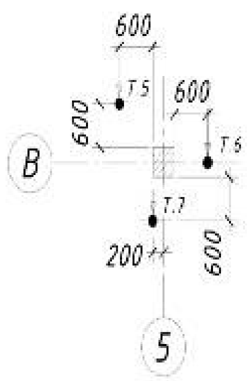

Figure 6 – Quality control in injection molding

a – the arrangement of sensing points at the axis 9/B; b – the arrangement of sensing points at the axis 5/B; c – results of the sensing

Conclusion. Thus the drillinjekted technology usage had allowed in a rather difficult geological conditions and in conditions of the existing building to realize the need for vertical transport connection of the designed production printing, and the monitoring confirmed the suitability of the elevator shaft for operation. Also the results of sensing of soils reinforced injection around the grounds confirmed the hardening of the soil and the adequacy of the base bearing capacity.

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