Up-to-date technologies of constructing foundations on loose soil in the city of Moscow

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Abstract. The area of residential buildings constructed in various soil conditions in Moscow has amounted to more than 15 million square meters for the past 20 years. Analysis of the work performed in 1990-2010 showed that various design and survey organizations carry out design and engineering surveys in different ways. Studies of the peculiarities of the construction of various objects in Moscow have shown a high efficiency of the examination of materials for geotechnical and environmental engineering surveys, as well as design documentation. There are cases when, in the course of construction work, the effectiveness of other, previously not provided for, design and technological solutions is confirmed. Many possible emergencies of existing buildings, as well as the facilities under construction attached to them, unreasonable, expensive and ineffective design solutions were excluded in the process of special examination of the projects.

1. Introduction
The area of residential buildings constructed in various soil conditions in Moscow has amounted to more than 15 million square meters for the past 20 years. More than 40 engineering and geological organizations and more than 100 design institutes are engaged in engineering surveys and design for construction of residential buildings in various districts of Moscow. Analysis of the work performed in 1990-2010 showed that various design and survey organizations carry out design and engineering surveys in different ways. This became especially evident after the analysis of projects of buildings erected on fill and soft soils in Moscow.
In order to unify this work, the Moscow City Construction Department decided to issue requirements or temporary regulations for conducting engineering surveys and designs of foundations in a consistent manner.

2. Overview
The effectiveness of the construction works, which begins, with arrangement of engineering network and finishes with erection of complex industrial and civil structures, depends on the results of qualitatively conducted engineering surveys. Short lead-time for engineering surveys and high-quality design and construction of structures contribute to this efficiency. This made it possible to ensure the construction of different facilities within the standard period.

The territory of the city, along with favorable for construction soil conditions, comprise unfavorable specific soil, which includes technogenic, loose sands, soft clayey soils, organo-mineral, swelling and heaving soils. Soft soil includes fills, loose sands, soft clayey soils, and organo-mineral and organic soils with a deformation modulus more than 5 MPa. This soil must be drilled to the entire thickness of the layer during surveys. Therefore, it is impossible to plan the scope of survey work without studying the archive materials.

The main problems of construction of buildings, structures, engineering networks of various types and purposes, associate with the construction of foundations. A number of researches point out that geological conditions of a large territory of Moscow are difficult and unfavorable for construction, due to the development of negative engineering-geological processes, that include changes in hydro-geological conditions, in particular flooding of the territory, karst-suffusion processes, landslides, and subsidence. On the territory of Moscow, the thickness of technogenic deposit ranges from 3 m to 20 m. This stratum is laminated, contains inclusions of variously sized stones and polluted with chemical elements. In some places, this layer is filled with construction waste: cement, concrete, metal products, and is covered with asphalt-concrete pavement. According to MGSN 2.07-01, pollution of the close to surface layers with chemical elements harmful to humans covers 25% of the city's territory (mainly in its central and eastern parts).

For many years, the availability of leading academic institutes, research organizations, design institutes, engineering research organizations, as well as the availability of construction organizations staffed with highly professional personnel and equipped with modern construction machinery has provide the possibility for creating and designing different types of foundations, as well as testing them in-situ in the Moscow area. The essential part of these decisions was later included in regulatory documents.

Nevertheless, accidents and deformation of structures sometimes appear either during the construction process or after putting the structure in operation.

However, there is no comprehensive consideration of all stages of construction, aiming at elimination of errors in engineering and environmental surveys and design, as well as in construction process. An analysis of the recent work (2011-2020) has showed that the main reason for the low quality of projects is the cost savings for soil study during engineering and environmental surveys. This leads to the adoption of expensive, incorrect, not always well-grounded decisions on the arrangement of the foundations of the designed buildings, and structures being under construction.

Often due to the lack of archival materials as well as the lack of the experience of construction in a proposed area, the scope of work can become too large. At the same time, the archival materials may not contain the data that are very significant for choosing a suiting type of soil basement and foundations.

Based on the analysis of the previously performed engineering surveys and investigations in the field of foundations construction, and based on the author’s experience both in these investigations and in those recently performed at different construction sites in Moscow, the specific features of en-
engineering surveys, design and construction of buildings and structures in difficult soil conditions have been studied.

The factors having an influence on the foundation design technology and installation procedure in the confined conditions through the city of Moscow (as an example) are listed below:

- buildings and structures existing together with active and out-of-service underground communications (water supply, sewerage, industrial pipelines, gas pipelines, communication tunnels);
- dense network of over ground urban transport, including railway lines;
- the presence of active and inactive subway tunnels;
- a lack of opportunities to temporally connect construction machinery and equipment to water and electricity supply facilities;
- a lack of possibility to organize construction due to the lack of free space within the construction site;
- the presence of karst, soft and specific soils, which require the application of special measures and specific methods for organization of construction on such soils.

Based on available information on the experience of construction in Moscow, the following factors affecting the design and placement of new structures near existing buildings have been established:

- the need to reduce vibration and shock effects from the operation of construction machinery;
- the need to strengthen the soil basement and restore the foundations under existing structures;
- the need to protect existing buildings from new construction by arranging “diaphragm wall” and sheet piling in the newly excavated pit;
- the need to protect nearby structures from deformations caused by construction dewatering of the adjacent construction site.

SP 22.13330.2016 "Foundations of buildings and structures" recommends additional limiting deformations for existing buildings and structures that fall under the influence of new construction. The values of these deformations, depending on the design features and technical condition of existing buildings and structures, are the following:

- the relative differential settlement \( (\Delta_s / L)_u \) - 0.0004 - 0.0024;
- limited settlement \( S_{\text{max}}^u \) - 0.5 - 5 cm.

Herewith, engineering and geological survey and a detailed structure survey specify the categories, namely I, II, III, of the technical condition of existing buildings and structures.

Two available technologies distinguish buildings and structures that fall under the influence of new construction:

1. These are buildings with a number of floors from 1 to 12, made of bricks, concrete, precast concrete or mixed construction material (with a service life of about 100 years or more). Often, the new construction or the reconstruction is carried out very close to or between existing structures. The foundations of these older buildings are often made of rubble.

2. These are mainly buildings or structures with a number of floors from 5 to 22, which include structures made of brick and monolithic or prefabricated reinforced concrete, bearing-wall structures and framed buildings, as well as structures made of mixes construction material. Since they were built in 1930-1940, at the beginning of the construction industry development, these buildings and structures have still existed.

The experience of reconstruction undertaken in Moscow in 1988-2020 has shown that four groups of measures usually successfully ensure the safety of building and engineering network that fall under influence of new construction.
1. Reinforcement of buildings and structures. Reinforcement includes such measures as covering weak parts of buildings with metal straps with the possibility of adjusting the tension forces with screw devices, carrying out cementation of underground parts, increasing the strength of the foundations material (many historical buildings have foundations made of rubble stone on lime mortar).

2. Implement soil hardening by various cementation methods. Strengthen concrete or reinforced concrete freestanding and strip foundations, including rubble foundations already reinforced with cementation. Implement pile underpinning.

3. Arrangement of cut-off walls between a preserved structure and a new construction accomplishes with erection of the wall made of jacked pipes or a row of driven piles. Jet technology with reinforcement is usually applied for installation of sheet-piles. Larsen sheet piles and “diaphragm walls” are also used.

4. Low impact construction technology, that is, reduction of shock and vibration effects from the operation of construction machines and mechanisms is also appreciated. In this case, rollers compact the soil in a static mode, and various jacking devices drive piles into the ground.

The effectiveness of the above pointed measures substantially depends on the groundwater level. Up to 3 often pressurized groundwater levels characterize many construction sites in Moscow to a depth of 30-35 m. as a rule, the upper groundwater level is at a depth of 2-3 m below the surface. In Moscow, up-to-date buildings have up to 60 floors above the ground and up to 5 underground floors used for parking lots. “Diaphragm walls” lowered to a depth of 30 to 35 m usually protect such underground structures when constructed, however, this often leads to a barrage effect. Therefore, the preventive measures applied for existing structures, as well as engineering network should take into account the processes and consequences of the appearance of a possible barrage effect.

As the analysis of the construction of deep (underground) parts of many buildings has shown, poorly executed "diaphragm wall" exposed to leaks. Advanced adhesive compositions are usually used for repairing these leaks. In many cases, pumps suck the water out of leakages periodically or within 24 hours. Occasionally, poorly made engineering survey may result in incorrect design and construction of “diaphragm wall” (often imperfect), and a foundation slab under low-rise building producing a small load on this slab may start to move upwards.

For execution of the high-quality preventive measures aimed at protection of the existing structures during construction works at the adjacent territory, all the problems concerning the design and organization of the preventive measures should be resolved basing on the data obtained from a detailed examination of the soil foundations, and footings of the existing structures.

In the cramped conditions of Moscow, there were cases when protection was required for both an existing structure and a newly constructed facility. This includes the construction of buildings and structures in the immediate vicinity of or above the subway tunnels or near the railway, etc. In the presence of a subway, it is necessary to reduce the shock and vibration effects imposed by construction machines and mechanisms on tunnel structures, and for a newly built object, it is also necessary to protect people and buildings from subway vibration by means of vibration isolators. Near the railway and highways, measures should be taken to protect the foundation soils of the structures from vibration settlement.

Loose and soft soils compose many construction sites in Moscow. The results of studies carried out as a part of the scientific and technical support for the construction of various facilities in Moscow are given below.

In the study of issues, the solution of which leads to the quality and efficiency insurance of engineering and environmental surveys, as well as design and installation of structures foundations in the cramped conditions of Moscow the following peculiarities of construction on fill soils have been established.
1. In Moscow, development of deep pits, and planning of the territories often results in the appearance of fills. The thickness of this soil may be up to 25 m. At many construction sites located in the southeastern part of Moscow, the average thickness of the fill soils is 4.5 m. In many cases, the physical and mechanical characteristics of the fill soil are different in strength and deformability in depth and in plan.

2. Commonly, fills at the territories of many construction sites in Moscow have been dumped together with construction waste (crushed cement mortars, concrete, reinforced concrete, brickbats, scrap metal, reinforcement, etc.).

3. Some territories proposed for construction earlier have been temporary or illegally used as waste dumps. Various chemicals usually saturate such fill soil. Besides, if these territories maintained household waste dumps they may generate gas. According to available data, the gas is usually of biological origin, mainly CH₄ methane.

When designing and installing foundations of buildings and structures on fill and soft soils in Moscow, the following factors should be considered:

- the possibility of using bulk and soft soils as natural bases;
- a relatively uneven location of various layers of fill and soft soil in plan and depth;
- a relatively uneven distribution of the physical and mechanical properties of the layer (layers) of fill and soft soil in plan and depth;
- a relatively uneven distribution of the values of the design settlement of structures located on fill and soft soil in plan and depth;
- the values of the design settlement of buildings and structures located on fill and soft soils, as well as the permissible unevenness of these settlements should possibly conform to the requirements of SP 22.13330.2016;
- the need for the design and construction of artificial foundations (sand bed, stabilized and compacted soil foundations, etc.) and pile foundations of various types with the values of the design settlement and its unevenness larger than specified in SP 22.13330.2016.

Numerous studies on structures deformations developed in Moscow have shown that low and incomplete results of engineering surveys are the main reason for the appearance of the deformation. SP 47.13330.2016 provides the main content of the terms of reference for engineering surveys. For specific soil conditions and supposed specific work, the terms of reference should be supplemented with the items corresponding to the relevant sections of the regulatory documents.

Analysis of some reasons for the structures deformations have shown that terms of reference designed for engineering surveying in the cramped conditions of Moscow city do not mistakenly contain some basic provisions of the norms:

- the stages of engineering survey to be performed;
- the presence of alleged hazardous natural processes and phenomena, specific soils on the territory of the proposed construction site;
- the requirement for the necessity of scientific support of engineering surveys;
- requirements for making predictions of changes in natural conditions;
- a transferred by the customer list of information on results of previously conducted investigations including complications observed on the territory during the construction and operation of structures, as well as deformations and emergency situations.
- the results of a preliminary visual assessment of the technical condition of supporting structures and the characteristics of buildings and structures falling under the influence of new construction;
- requirements for engineering surveys on the territory of structures falling under the influence of new construction and requirements for examination of the soils foundations of these structures;
requirements for the prediction development of hazardous engineering and geological processes, and changes in the hydrogeological conditions of construction site;

- requirements for the researches on karst, technogenic soils, organomineral and organic soils.

If these items escape the real program of engineering survey, the obtained survey results may not be sufficient for design.

The prediction of hydrogeological conditions comprises the prediction of changes occurring during the construction period, including assessment of the water flow into the excavation, the effect of drainage, etc., and during subsequent operation period, including assessment of the possible barrage effect, the influence of wall and bed drainage, the possibility of flooding the territory, etc.

During the construction of buildings and structures belonging to the third geotechnical category and to the first (I) and second (II) levels of responsibility, the scope of woks as per geotechnical surveys should be increased by 40-60%, against the recommended by the specified regulatory documents.

As the analysis of the results of scientific and technical support of engineering survey in the Moscow region has shown, several factors that complicate the survey, design and construction of the facilities can occur simultaneously at the same construction site. In many areas of Moscow, organomineral and organic soils, residual soils, karst, loose sands, and soft water-saturated clay occur under technogenic (fill) soils. Moreover, it may still be flooded or potentially flooded soil. Therefore, when drawing up the terms of reference and the program of the engineering survey, all the requirements of the relevant parts of SP 11-105-97 must be fully taken into account. SP 11-105-97 also includes requirements for surveys in flooding areas and built-up areas (including historical buildings).

The list below provides the frequently encountered shortcomings of engineering and geological studies carried out at the construction sites of new buildings and structures erected on fill and soft soils:

- when determining the characteristics of specific soils, additional studies in pits, studies by geophysical methods have not performed, and, as a result, there is no possibility for conducting a comparative analysis of their distribution over the area and depth;
- strength characteristics of loose sands were not determined by in-situ sounding, as well as in-situ plate bearing test has not been conducted for assessment of deformation modulus;
- the filtration consolidation coefficient for water-saturated clayey soils, with a liquidity index of more than 0.5, and organic-mineral soils has not been determined;
- the values of the degree of peat content and the degree of decomposition of plant residues for organo-mineral soils have stayed unknown;
- as for fine and silty sands and silty clay, their tendency to form floating sand has not been assessed.

The main mistakes in the design and construction of various buildings and structures located on fill and soft soils in Moscow (based on the analysis of works in 2008-2020) can be considered as follows.

1. Accidents and deformations of existing buildings, structures, as well as engineering network that falls into the construction zone when using construction machines and equipment with a maximum degree of shock and vibration effects on the site of a new adjacent structure under construction.

2. The lack of information on the technical condition of structures and on the results of the existing soil foundation examination causes incorrect adoption and implementation of preventive measures designed to ensure the protection of existing buildings, structures, as well as engineering network that fall into the construction zone.

3. Disagreement of the monitoring cycles and their frequency with the mode of construction work, at the new adjacent construction site results in incorrect results of geotechnical monitoring.

4. Incorrect construction of dewatering at the adjacent construction site.

The presence of specific soils, dangerous geological and engineering-geological processes, abundance of the subway tunnels and communications in the underground space of the city, as well as the presence of buried foundations, tunnels and communications in the areas of historical buildings,
complicates and often makes the construction in Moscow very expensive. A lack of the scope of engineering surveys, including geophysical surveys, is a main reason for the above “problems”. The results of studies on the peculiarity and efficiency of foundations installation, carried out during the construction of structures located on construction sites with fills and soft soils has shown that current regulation documents suppose the construction on fills in the following cases:

- the embankment of soil and industrial waste should be regularly erected (Type I);
- dumps should consist of soil and industrial waste that comprises rock debris and gravel soils, coarse sands and slag (Type II).

According to the existing practice, fill soils are rarely used as natural foundations of responsible buildings and structures in Moscow city. These soils can be used as bases for temporary, non-responsible structures.

Fills (according to projects) are mainly cut off and replaced with sand. In the absence of hazardous chemical elements, gases and biogas in the fill soils, the part of the fill below the underground floors is usually penetrated by piles. These types of structures have a solid reinforced concrete foundation slab (foundation frame). The underground part, depending on the presence of existing buildings, structures, as well as engineering network, is erected in excavations protected by different types of sheet piles, or a “diaphragm wall” installed by using various technologies.

An anchor system of 1 or 3 floors usually protects the above pointed types of excavations. The size of the anchor system depends on the depth of the excavation and the properties of the soil or on the sequence of construction work.

In many cases histories, “diaphragm wall” was perfect at a high groundwater level, that is, it entered dense, low-permeable clay soils. When the “diaphragm wall” was not perfect, water was pumped out of the excavations, according to a technology that takes into account the possible subsidence of the soils of the foundations of structures, as well as engineering communications falling under the influence of new construction.

At numerous facilities in Moscow, at the base of existing buildings, structures, as well as engineering network that fall into the new construction zone, soil has been successfully improved by cement injection. For this purpose, Portland cement as well as modern microdisperse cement has been used.

Herewith, various types of sandy and clay soils, at different states, occurring in the deformation zone, are subject to strengthen. These soils often have low values of strength and deformation properties. Specially and gradually made fills can mainly appear during the engineering preparation of large areas for construction. One of these objects is the construction site located at the Nekrasovka district of Moscow. The main part of this site is the former territory of Luberetskiy irrigation fields. After removing the top soil a layer, the entire area was covered with fresh clean sand compacted to a certain extent. Soil foundation under a few buildings was improved by cement injection. Other buildings were constructed on the compacted sandy foundation made of sand ranging in size from fine to coarse.

Soil cementation was carried out using the following technology:

Stage 1: Cement was injected from the planned ground surface at a distance of 3-4 m, to a depth of 8-10 m, creating a 1-1.5 m wide “belt” like a “diaphragm wall”.

Stage 2: After the construction of 17-20-storey buildings up to the 3rd floor, the cement-sand mortar was pumped into the soil basement through the pipes inserted into the monolithic reinforced concrete slab.

The cement composition, water-cement ratio, pressure and sequence of solution supply were selected according to special project requirements.

The total settlement of these structures during construction and a year after was only 4-5 cm.

The same technology was used to create a waterproof screen below the bottom of the excavations, protected by “diaphragm wall”. Destroyed limestone was strengthened with deep anchor system prior to the installation of a “diaphragm wall”.
Soft clayey soils with deformation modulus of 7 MPa were stabilized by cementation at a depth of 24 m.

Soft soil under an 85 cm thick reinforced concrete slab foundation that had suffered settlement up to 20 cm was strengthened by the same method.

Areas subjected to karst development include territories with widespread water-soluble rocks (limestone, dolomite, gypsum, chalk, etc.). The foundations installed on these territories were designed taking into account the development of karst processes.

Anti-karst measures were designed for numerous buildings and structures located in territories classified as potentially hazardous and hazardous in terms of karst-suffusion development. Continuous foundation structures were installed under those conditions. The foundation of 17-storey buildings comprised a monolithic reinforced concrete slabs.

According to the requirements of the Moscow city standards, soil foundations composed of water-saturated organomineral (silt, sapropels, peat soils) and organic soils (peats and sapropels) or those which include these soils should be designed taking into account their specific features: high compressibility, variability and anisotropy of strength, deformation and filtration characteristics, and changes occurring in the process of consolidation and long-term development of settlement over time. Thixotropy and possible gas release (methane, carbon dioxide) should be considered for silt.

In order to reduce the possible settlement of a 22-storey panel residential building, prefabricated reinforced concrete composite piles with a cross section of 40x40 cm, 15 to 21 m long, were driven into leader wells below a monolithic reinforced concrete slab. The piles were driven into dense sands to a depth of 1 to 1.5 m. The bearing capacity of the piles, according to the results of static tests, was 110-120 tons. The design bearing capacity of the piles was determined taking into consideration possible negative friction from sludge settlement with a decrease in the groundwater level.

Organomineral and organic soils located close to the surface were replaced with layer-by-layer compacted coarse and medium sand, as well as crushed stone and gravel.

Formed many years ago (1932-1934), the territory covered with fills has been often used as a dump for industrial and household waste, and in many cases it has becomes gas generating. The main source of biogas is household waste, the main representative of biogas, which is dangerous for people, is methane (CH4).

According to the current regulatory documents of the city of Moscow, gas-geochemically hazardous (CH4> 1.0% vol., CO2 up to 10% vol.) areas have been wooden around the constructed buildings and structures.

On potentially hazardous gas-geochemically (1.0%> CH4> 0.1% vol., CO2> 0.5% vol.) areas, landscaping areas can be located around the constructed buildings and structures. For protection of buildings and structures in gas-geochemically potentially hazardous areas, gas drainage systems of the soil massive should be created at the base of structures. These measures include laying of crushed stone-sand layers of small thickness at the base of foundations, installation of gas insulation systems under the bottom and outside the underground parts of buildings and structures, and installation of ventilation systems for underground buildings.

The results of an effective a layer-by-layer compacted sand foundation in Moscow constructed with respect to the current instructions and regulations are shown below.

The total thickness of the compacted sandy base of buildings ranged from 2.1 m to 4.66 m at experimental sites at various sites. The thickness of the individual compacted layers of sand, depending on the type of vibratory roller, was 45 cm, 60 cm and 75 cm.

The sands were compacted with self-moving vibratory rollers, such as Bomag BW 211 PD-5, Hamm 3412, Cat CS64B, etc. with a working weight of ≈12 tons; Bomag BW 216 D-5, Roll RV-17 DT 17T, etc. with a working weight of ≈16 tons; and Bomag BW 219 DH-5, Hamm 3518, Rolling RV-21 DT, etc. with a working weight of ≈16 t.
Coarse, medium and fine sand composed the compacted base. The sand was compacted at a natural moisture content of $w \approx 5-14\%$. To establish effective operating parameters, the number of the roller passes during test compaction was from 2 to 22 times, and during the main compaction - from 8 to 14 times. Different levels of vibration mode were set for the rollers: the first pass - no vibration; the second and further passes - maximum, the last pass is minimal.

The difference in the values of the maximum density of different sands with the same parameters of compaction effect is the difference in their mineralogical and grain size distribution (type of sand), moisture.

For all types of investigated sand (gravelly, coarse, medium size, fine), the following maximum values of the physical and mechanical characteristics of compacted sand were obtained:

- The density of the sand $\rho_{\text{max}}$ ranged from 1.87 to 2.18 g/cm$^3$.
- The density of dry soil $\rho_d$ varies from 1.68 to 1.96 g/cm$^3$.
- The porosity coefficient $e$ ranges from 0.36 to 0.58.
- The sand compaction coefficient $k_{\text{com}}$ ranges from 0.98 to 1.01 CU.
- Internal friction angle $\varphi$, varies from 29.5 to 41.9 degrees.
- Specific adhesion $C$ varies from 0.001 to 0.004 MPa.
- The deformation modulus $E$ varies from 32.15 to 58.29 MPa.

An important factor in the construction of compacted bases of gas-tight and gas-inert sands is the required density and moisture content of the base soils below the first compacted layer. At low density and high moisture content of soils located below the first compacted layer, in spite of all technological and technical methods, the sand unable to be compacted.

Field studies have shown that for compacted bases made of gas-impermeable and gas-inert sands arranged by replacing gas-generating soils, the porosity of compacted sand is of great importance. The porosity of compacted sand decreases with increasing density, with a change in the compaction coefficient $k_{\text{com}}$, from 0.94 to 1.00, porosity $n$ decreases from 50% to 40%.

Sands of large or medium size compacted to maximum density values ($k_{\text{com}} \geq 0.98$) have $\approx 30\%$ of pores. This is very important for the passage of ground gases outward through the compacted sand in the building's sinuses. Studies have confirmed that these sands can be compacted to maximum density values at moisture content different from their optimum moisture content $w_{\text{opt}}$. This property makes it possible to carry out work on compaction of sand for gas protection of structures throughout the year notwithstanding the weather conditions (at positive temperatures).

In the conditions of Moscow, the following areas of activity in the field of construction can be considered:

- investment activity of any kind in the construction industry;
- engineering-geological and engineering-ecological surveys;
- development of projects of all types in the construction industry;
- construction and installation work;
- repair and reconstruction of existing buildings and structures, as well as engineering communications;
- the adoption of preventive measures to ensure the operational suitability of existing buildings and structures, as well as engineering communications, when new structures are adjacent to them.

The above types of construction activities are accompanied by a threat to property interests of organizations and companies, participants or performing tasks according to the activity. In this case, the following should also be considered: harm to the property of other persons and organizations, harm to the health and life of employees, citizens, and the environment.

When performing the above activities, the following cases should be included in the list of risks when insuring the relevant activities:
- destruction, damage, elimination of existing buildings and structures, engineering network, as well as all types of underground structures and communications of the subway and other services;
- destruction, damage, destruction of buildings and structures attached to existing buildings and structures, utilities and newly constructed buildings and structures under construction on free territories;
- damage caused to complex and expensive construction machinery and equipment, construction equipment, construction materials;
- harm caused to employees of construction and survey organizations;
- harm caused to the health, life and property of other persons;
- damage to the underground and aboveground ecological environment.

To exclude the above cases, appropriate insurance contracts must be concluded. At the same time, the following can act as insurers for various types of contracts in the field of construction: investors, customers and developers (in order to protect the invested funds from destruction or damage to property); construction and survey organizations (in relation to their own property or civil liability to third parties); self-regulatory organizations (in relation to the civil liability of SRO members to clients and customers).

Studies of the peculiarities of the construction of various objects in Moscow have shown a high efficiency of the examination of materials for geotechnical and environmental engineering surveys, as well as design documentation. There are cases when, in the course of construction work, the effectiveness of other, previously not provided for, design and technological solutions is confirmed.

Many possible emergencies of existing buildings, as well as the facilities under construction attached to them, unreasonable, expensive and ineffective design solutions were excluded in the process of special examination of the projects.

### 3. Conclusions

1. The cause of accidents and deformations of existing buildings, structures, as well as engineering communications that fall under the influence of the construction of a new attached structure are usually the results of poor-qualitative and inadequately performed engineering surveys, and, as a consequence, the design and arrangement of unreasonable preventive measures. To prevent errors, the norms of the city of Moscow have been created.

2. In the city of Moscow, during the construction of various buildings, structures, as well as engineering network in cramped conditions, on fills and soft soils (loose sands, weak clay, organomineral and organic soils, etc.) modern technologies have been successfully applied. These technologies are included in the special regulatory guidelines for the city of Moscow.

3. The main criterion (condition) for effective construction in the cramped conditions of Moscow is strict adherence to the current regulatory documents of Moscow and the Russian Federation on construction, scientific support at all stages of the object's life cycle.

4. Engineering and ecological surveys on the territory of Moscow, must be performed in stages with respect to special instructions issued for Moscow region, that is, engineering survey should be carried out at the stage of choosing a construction site for design (project and working documentation) and during construction.

5. For high-quality performance of engineering and environmental surveys on the territory of Moscow, it is necessary to take into account complicating factors, that is, the presence of technogenic (bulk) soils, soft soils (loose sands, weak clayey, organomineral and organic soils, etc.) on the territory of one construction site.

6. The Moscow experience in the development of regulatory documents and instructions for the construction of various buildings, structures, as well as engineering communications in cramped conditions, on fills and on soft soils (loose sands, weak clayey, organomineral and organic soils, etc. etc.)
is a model and example for a large number of cities that have similar problems and do not have developed special norms and recommendations for their territories.

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