Saimaa University of Applied Sciences
Double Degree Programme
Civil and Construction Engineering

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Building inspection and condition monitoring stages in Russian Federation

Bachelor’s Thesis 2012

Abstract

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Building inspection and condition monitoring stages in Russian Federation, 56 pages, 1 appendix
Saimaa University of Applied Sciences
Double Degree Programme
Civil and Construction Engineering
Thesis 2012
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The goal of this project was to study stages of building investigation and inspection in Russian Federation during preparation for reconstruction works or near new construction sites.

All information was carried out through field research works held in 2010-2012 by “Georeconstruction” closed corporation. Also public Internet resources were used for studying national codes and describing objects of investigation and monitoring. The emphasis was placed on the use of non-destructive investigation methods.

The achieved results represent the experience of investigation works and current technological level of wide spread methods used in Russia.

Keywords: investigation works, concrete testing, non-destructive testing methods

CONTENTS

1. INTRODUCTION

Inspection and investigation of technical condition of buildings and its structures is one of the most needed areas of construction activities nowadays. Ensuring reliability of buildings, to conduct the repair work, as well as the development of project documentation for reconstruction buildings and structures is a wide field for research and innovation. The volume of surveys of buildings is increasing every year, which is a consequence of several factors: their physical and moral deterioration, and reconstruction of industrial buildings, low-rise renovation of old buildings, changes of ownership and a sharp rise in property prices, land, etc. It is especially important when conducting surveys of various kinds of man-made and natural factors (fire, earthquake, etc.), the renovation of old buildings and structures that are often associated with a change of operating loads, change of the design schemes and the need to consider modern building design codes. This work uses experience of construction investigation of “Gorkovskaya” subway station (ground-level lobby), Naval Cathedral in Kronstadt, aerotanks of wastewater treatment plant on White Island and visual inspection of living houses near Zanevskiy avenue in St. Petersburg.

2. LEGISLATIVE BASIS OF INVESTIGATION

Investigation activities in Russian Federation are held according to main national codes:

- ГОСТ Р 53778-2010 (GOST R 53778-2010) – national standard “Buildings and structures. Rules of the survey and monitoring of the technical condition".
- Territorial construction codes
  ТСН 50-302-2004 (TSN 50-302-2004) for St. Petersburg.

2.1 National Standard of survey activities

First mentioned National Standard, GOST R 53778-2010, is intended for use in construction in surveys and monitoring of technical condition of buildings and structures, the design specifications for project, inspection and monitoring of buildings and structures, as well as the project documentation.

Appendix A of the National Standard contains set of measures to ensure safety of operation of buildings and structures.

The National Standard is applied for following works:

- Complex survey of technical condition of buildings and structures for reconstruction or repair projects
- Survey of technical condition of buildings and structures to evaluate the possibility of safe operation in the future or the need of restoration or strengthening of structures
- General monitoring of the technical condition of buildings and structures to identify objects with changed stress-strain states to assess the need of detailed surveys
- Monitoring the technical condition of buildings and facilities that fall within the zone of influence buildings and natural and man-made influences, to ensure the safe operation of these buildings and structures

- Monitoring the technical condition of buildings and structures that are in limited operability or emergency condition, to assess their current technical condition and activities to eliminate an emergency condition
- Monitoring the technical condition of unique constructions, including high-rise and large span buildings and structures and its bearing structures to prevent accidents and collapses.

The National Standard requirements do not apply to other types of surveys and monitoring of technical condition of the transportation constructions, waterworks and drainage facilities, pipelines, underground structures, mining engineering, underground works, as well as for works associated with the forensic examination of construction.

2.2 Territorial construction codes

Territorial codes are developed and published by local authorities in collaboration with research institutes in various regions of Russia. The code TSN 50-302-2004 mentioned above has been composed by St. Petersburg commission of experts in the field of foundations, basement structures and underground structures public organization.

Using territorial codes allows taking into account local geological, climate conditions in constructions projects. For example, current code for the St. Petersburg region takes into account following negative factors:

- Thick layer (up to 30 m) of weak non-uniform soils, including thixotropic soils in most areas of the city
- High level of groundwater, including caused by man-made activities
- Alluvial, made grounds on the banks of rivers and by the bay with presence of peat and places with large peat layers.
- Hydrodynamic processes associated with surface exposure by water and groundwater, that causes waterlogging, mechanical and chemical suffusion of soils and quicksand phenomena

- Processes associated with freezing-thawing soils (frost heave, subsidence during thawing)
- Availability of existing buildings with defects caused by irregular settlings, including those due to lowering of groundwater level (temporary or permanent)

The territorial code also contains appendixes which have descriptions of typical states of various buildings, which help to determine category of technical condition. This information is used to finish report of investigation.

3. TARGETS OF INVESTIGATION ACTIVITIES

3.1 Industrial buildings reconstruction projects

More than 40% of St. Petersburg area is occupied by industry. During last 10 years there are tendency to move industrial companies out of the city centre to special industrial zones (for example, Parnas zone). Emptied buildings can be redeveloped according to modern needs, so new reconstruction projects require detailed inspection of load-bearing structures. One of the most famous examples of such reconstructions is the new United Documents Centre, which was constructed in old industrial buildings of ex-spinning mill (ОАО «Прядильно-ниточная фабрика им. С.М.Кирова»). Due to its historical value, the facades were not touched.

Figure 3.1. Buildings of former Spinning mill.

Figure 3.2. Top view of Spinning mill reconstruction project.

3.2 Historic buildings reconstruction

Nowadays lots of historic constructions are in poor condition, some of them are in emergency state. For example, the Naval Cathedral in Kronstadt has to be renovated due to large cracks in walls of counterforts and main entrances.

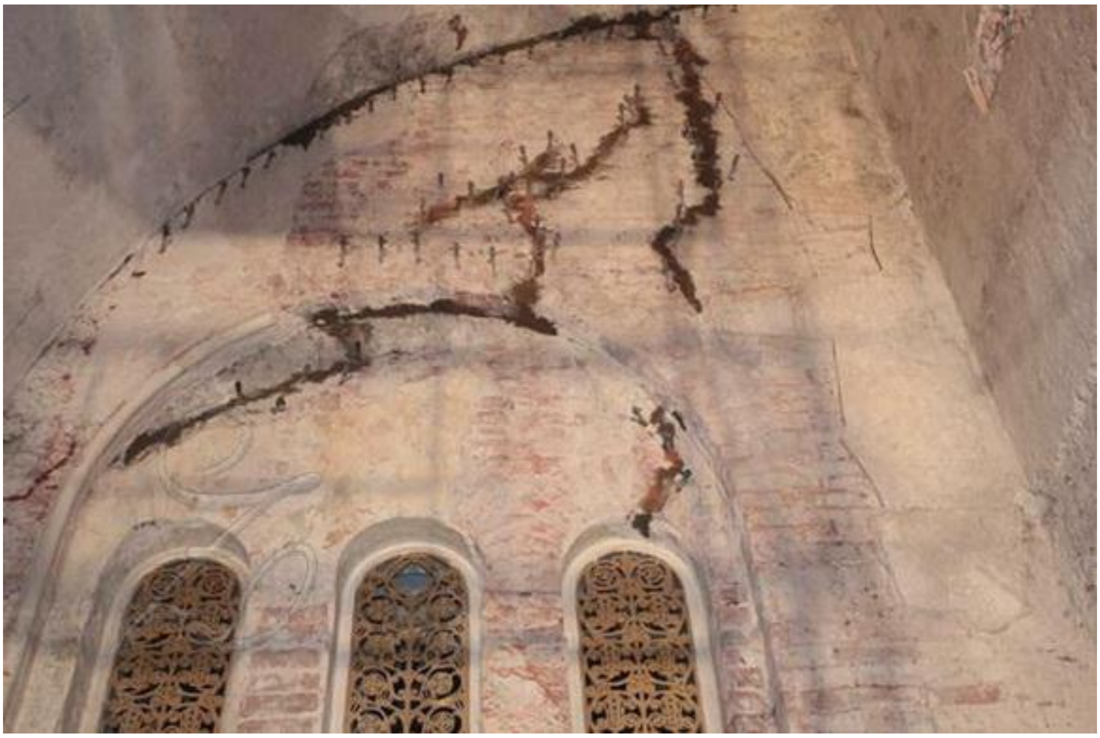


Figure 3.3. Cracks in masonry of a counterfort.

3.3 City infrastructure constructions reconstruction and repair

The city of St. Petersburg has the deepest underground railway system in the world. Lots of ground-level lobbies were built in 1960s-1970s and now require repair works or reconstruction to comply with modern needs of the city. As an example of investigation works before such reconstruction the vestibule of “Gorkovskaya” subway station will be examined.

Figure 3.4. Demolition of overhead part of the lobby.

As well as the city has public facilities, such as the subway system, there are also special constructions needed for keeping city infrastructure functional. One of them is wastewater treatment plan on Beliy (White) Island nearby the Gulf of Finland. The system of sewage aeration was constructed in 2007 in close collaboration with Finnish company Kemira. Nowadays the plant purifies sewage water to 90-95% level to prevent pollution of the Baltic Sea. After the construction works were finished and the technological process was launched, some problems with concrete aerotanks (needed to saturate the water with air to grow treating microorganisms.) were found, so detailed inspection of its walls was held.

Figure 3.5. Aerotank of the Central Aeration Station emptied for service.

3.4 Monitoring of condition of buildings nearby new construction site.

Monitoring of the main load-bearing structures of buildings located in the 30 meter zone from the area of new construction or renovation is required to conform national code GOST R 53778-2010.

Monitoring is needed to determine irregular settlements cause by construction works nearby and to prevent harmful effects caused by them.

Monitoring of buildings includes:

- Photos of main load-bearing structures and existing defects existing at the beginning of the period of construction (*photofixation*)
- Installation of beacons to detect cracks and defects in the walls of the building
- Periodic monitoring of sediments by geometric leveling marks installed on the building prior to construction using land-surveying tools
- Regular monitoring of installed beacons
- Monthly reporting on the status of customer observed buildings, if necessary

Monitoring allows suspending of construction if harmful tendencies were detected and make required arrangements to protect existing buildings, reducing total cost of the project. Cities like St. Petersburg have districts with thickening construction sites, so such monitoring works are required almost on all projects today.

4. MAIN STAGES OF BUILDING INVESTIGATION AND MONITORING

4.1 Contract signing stage

Each investigation project starts with choosing company that can provide required services and has investigation license. After that usually a tender is held and the company which has won it prepares documents needed for signing contract.

Contract includes signed technical tasks list; typical technical tasks list contains:

- Information of objects to be inspected (address, persons in charge)
- Reason for investigation
- Information about the client and the implementer
- Common description of tasks
- Terms of works
- Initial documents given by client
- Detailed description of investigation stages
- Requirements of work processes and results
- Reporting requirements
- Responsibilities list

Usually the payment for the investigation is divided into two parts. At first, a prepayment is made, typically 50% of total cost of the project. After all works are finished, the rest of the money is being paid.

4.2 Organization of pre-investigation process

Selection and studying of baseline data precedes field works and can be done using following technical documents:

- Working and executive drawings of architectural and structural parts of the project, acts of acceptance of the surveyed structures by the authorities, passports and certificates for materials and products, if available;
- Building maintenance materials: technical passports, repair journals, settlements measurements implemented by geodetic service, construction deformations, piezometric and other observations of the aggressiveness and the level of groundwater, internal environment parameters (for industrial buildings), etc.
- For industrial buildings: schemes, plans, characteristics of equipment and machinery located in a building that affects the technical condition of the building structures. Indicators such as fumes, soaring, dust, altitude, availability of parts, high voltage, the presence of hot surfaces, spillage of aggressive solutions.

This is followed by live-inspection of building structures, carried out as described above in two stages: the definition of the general condition of building structures and a detailed survey of building structures. Data on loads, determination of deflections and strains, measurements of cross sections, revealing the degree of wear and tear of building structures by identifying its defects and damages, physical deterioration, determination of concrete strength and mortar using non-destructive methods, opening structures and digging explorations shafts with sampling and laboratory testing of materials is being implemented according to tasks list.

4.3 Field work stages

After receiving of the prepayment, main works are started. Stage's details depend on each investigation project, here is typical work list of apartment block investigation that is located within 30-meter zone of new building site (If the building consists of several sections, there is no need to inspect all sections, if they are out of zone of possible influences).

Table 4.1. Field works categories

Type of works	Description
1. Foundation inspection and soil testing	1. Implementation of exploring shafts for definition of basement technical condition. Taking examples of soils and testing them in laboratory (in case of pile basement, the examples are taken under the raft foundation.) 2. Dynamic sounding of ground to find out actual soil density. 3. Verification calculations of load-bearing capacity of the ground. 4. Checking up stress limits of the soils (for strip foundations).
2. Inspection of technical condition of main load-bearing and envelope structures	1. Studying of initial documents, drawings and plans. 2. Visual examination of structures. Photofixation and registering of defects. 3. Selective measurements of structures. 4. Selective examination of

	material strength (Shmidt hammer “Beton Control” for concrete) 5. Concrete strength testing using ultrasonic tools (“Pulsar-1”). 6. Examination of flights of steps and landings. 7. Examination of roof structures and attic. 8. Measuring of wall’s list. 9. Evaluation of technical condition of structures and results analysis. 10. Conferment of category of the building according to codes (TSN 50-302-2004, SP 13-102-2003, GOST R 53778-2010). 11. Photofixation of defects in each apartment and utility rooms. 12. Developing of future service and safety operation recommendations. 13. Report compilation based on instrumental measurements.

4.4 Long-term monitoring

In case of prolonged monitoring of building(s), additional reports are made at the end of each period, stated at contract signing stage. Under some circumstances the period can be shortened. The additional reports include changes of parameters being examined and recommendations.

5. SEISMOACOUSTIC INVESTIGATION METHOD

5.1 Physical premises of defects revealing in concrete structures

In the application of seismic methods, according to the dynamic analogies, mechanical vibration system excited by blows can be described by the same equations as electrical circuits, and their solutions are similar. In line with this, with a sledge hammer blow (hammer) on the plate nearby the joint structures, they radiate energy due to friction of the particles (frequency-dependent phenomenon) and its displacement. This energy is distributed in the structure itself, causing the oscillatory processes. The kinematic characteristics of the system, namely the cube root of the speed of waves characterize the strength properties of any concrete. Primarily, this is rigidity and its variation. In other words, the change rate can reveal deformation of structures (cracks, voids, rigid joints changes, etc.). In addition, there are the dynamic characteristics of the kinematic wave energy. This amplitude-frequency and amplitude-phase frequency characteristics determined by multiply reflected waves from the boundaries of the layers (the type of reverberation).

It should be noted that both the kinematic and dynamic characteristics of vibrational non-stationary processes are random and depend on the quality of production design (the quality concrete consolidation, especially in places with fixtures, fittings and concrete bonding, etc.). These features must be considered when evaluating the continuity of the structure.

5.2 Quality and dimension control of piles using non-destructive methods

Main function of piles in deep foundations is to maintain the structural strength and integrity under load.

Building a profile of the structural integrity of a prefabricated or directly on the site drilled piles reflects all the factors of influences:

- Underground conditions
- Quality of soil or concrete
- Construction method
- Quality of pile production

Under influence of a hammer pile is subjected to stress, which in case of excessive exposure may cause structural damage. Assessment of structural integrity of driven piles and bored piles can be conveniently and economically accomplished using of non-destructive testing (NDT), also known as a test for the integrity of the pile (Pile Integrity Test - PIT).

As well as by driving prefabricated piles, production of bored piles also can cause formation of different defects. National Code GOST 5686-94 ("Soils. Field methods of testing by piles") regulates the amount of the following tests:

- Up to 1% of total number of piles at this facility, but not less than 6 units – by dynamic load (driven piles);
- Up to 0.5% of the total number of piles at this facility, but at least two pieces - by static load.

The probability that a defective pile will be tested is quite small. Additionally, if the test by static or dynamic loads reveals defective pile, confidence in all piles characteristics on the site is reduced.

CJSC “Geostroy” uses two methods of testing:

- The method of acoustic scanning
- Seismo-acoustic method (SIT)

5.2.1 The method of acoustic scanning (two or more wells)

The emitter and receiver are installed on different conductive tubes, it is important to ensure that they were located at one level. For conducting these tests, the holes are formed in advance by means of two steel or plastic pipes. Defects that are between the tubes, well defined, but since there is no radial scanning outside the tubes there is a "dead zone" in which the defects cannot be determined.

Explore the major part of the body piles can, using the required number of tubes (Figure 1). The number of conductive tubes significantly increases with the diameter of the pile (Figure 2).

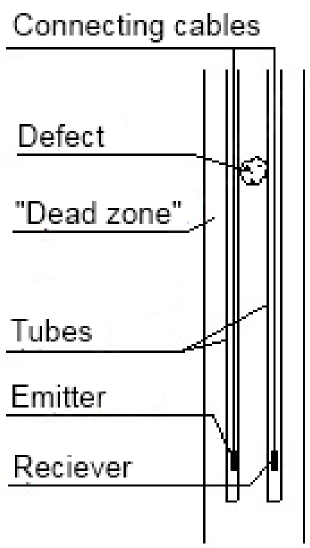


Figure 5.1. Elementary diagram.

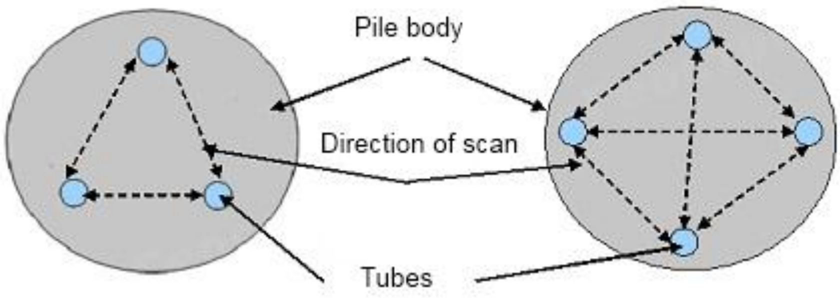


Figure 5.2. Scanning schemes: a) scanning in three areas of measurement, and b) scanning of the perimeter and diagonals.

The test speed corresponds to the previous speed tests. The cost of the test also depends on the cost of the unit conducting tubes.

5.2.2. Seismoacoustic method

This method has several advantages. The main ones, of course, are the low cost of the work at a high speed and the opportunity to experience as part of an existing pile grillage. Apparently, for these reasons the seismoacoustic method gains in popularity and gains the confidence of engineers on construction sites in St. Petersburg.

The seismoacoustic method based on the theory of elastic wave propagation in the body of the object. Such wave is excited in a pile with a pulse from the impact hammer tool, which creates the input power pulse with duration of less than 1 ms, and this does not cause any damage as a result of exposure. The reflected wave is recorded by the accelerometer, which is installed so that its measurement axis is parallel to the axis of the pile. The signal is then amplified and transmitted to a personal computer. The software allows you to build a trace - a graph of the sound wave velocity along the length of the pile. Analysis of reflectograms makes it possible to fix the defects in the trunk of the pile and to determine its length. Testing provides data on the rate of wave propagation and impact force for various building elements (precast concrete piles, bored piles and piles of steel pipes filled with concrete, wood piles, etc.). These data helps to assess the continuity and the physical size of the piles, its cross-sectional area and length, as well as the integrity and density of the material. It should be noted that the seismoacoustic method does not provide information on the bearing capacity of piles.

To obtain reliable results it is necessary that the following conditions:

- Headroom of piles should be easily accessible, horizontal, with no debris;
- Standing water, laitance, cracks or cavities are not permitted on the tip of piles;
- Bored piles are tested no earlier than 7 days after filling or after concrete strength reaches 75%;
- In the case of piles with a diameter exceeding 500 mm, the accelerometer is installed in at least three places in order to evaluate the continuity of the pile near the tip of each of the selected area;
- The impulse has to be produced to the axis of the pile, but at a distance of less than 300 mm from the accelerometer.

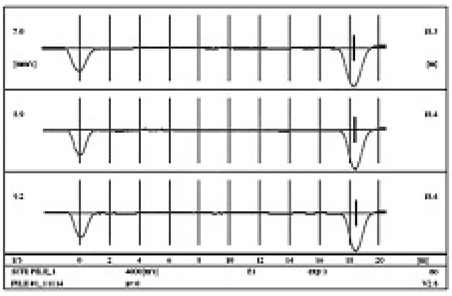


Figure 5.3. Example reflectogram of a 18,4 meter pile.

Figure 3 shows a trace of a driven pile, whose length is 18.4 meters and by the results of the test the length is 18.4 m, so no defects are observed.

5.2.3. Seismoacoustic investigation of complex structures

During investigation works of “Gorkovskaya” subway lobby was used this method as quick and quite precise, due to round in plan construction of the lobby.

For implementation of the measurements were used the following tools:

- KD-29 vibration sensors (sensitivity 3 mV/sec^2, frequency range 1-35000 Hz), , ADC,
- Signal amplifiers by "Brüel & Kjær" (Denmark)
- Analog-to-Digital converter (“Maya”) with USB interface
- PC computer (laptop)
- Software: software spectral analysis, correlation, wavelet analysis MathCad frameworks.

Accuracy of measurements: the frequency of 0.1 Hz, the amplitude of ± 0,5 dB.

To determine the defects in the basement under the base plate of machinery room, as well as to survey soils under the foundation slab basement in accordance with the scheme of the measurements shown in Figure 4, the excitation of seismic waves was produced by a sledge hammer weighing 8 pounds and registered by seismic sensors. Sample installed sensor is presented on picture 5.

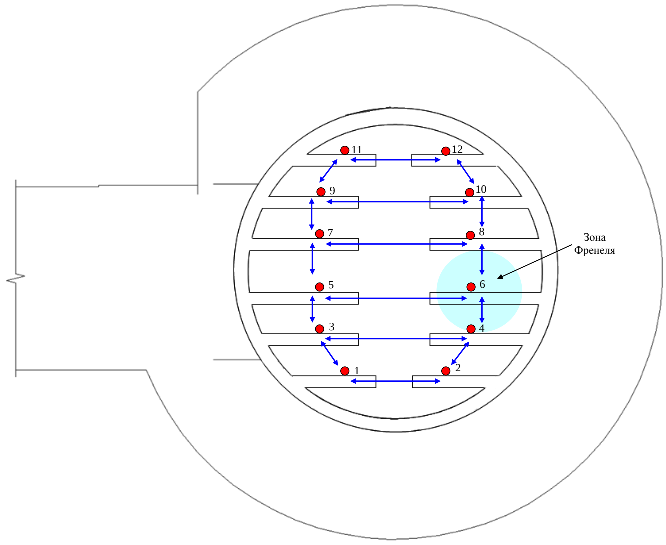


Figure 5.4. Diagram of measurements in the base plate under the machinery room.

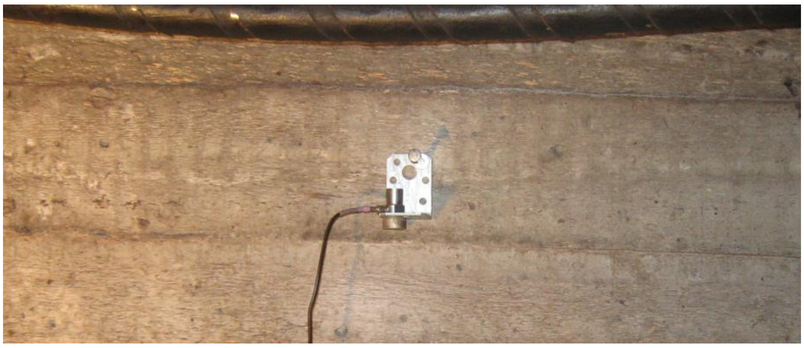


Figure 5.5. A vibration sensor installed on basement wall.

Registration of seismic signals was produced simultaneously for the two sensors. Thus obtained amplitude-time implementation subsequently analyzed using specialized software, including Fourier analysis and wavelet analysis of signals. Also was checked integrity of joint of basement floor and walls, using another sensor installation scheme (Figure 6). The amplifiers should be installed near the sensor to prevent fading of weak signal from the sensor.

Picture 5.6. Sensors by two sides of joint.

Comparing results of several tests allows to evaluate joint condition of round structures, such as shown on Figure 7.

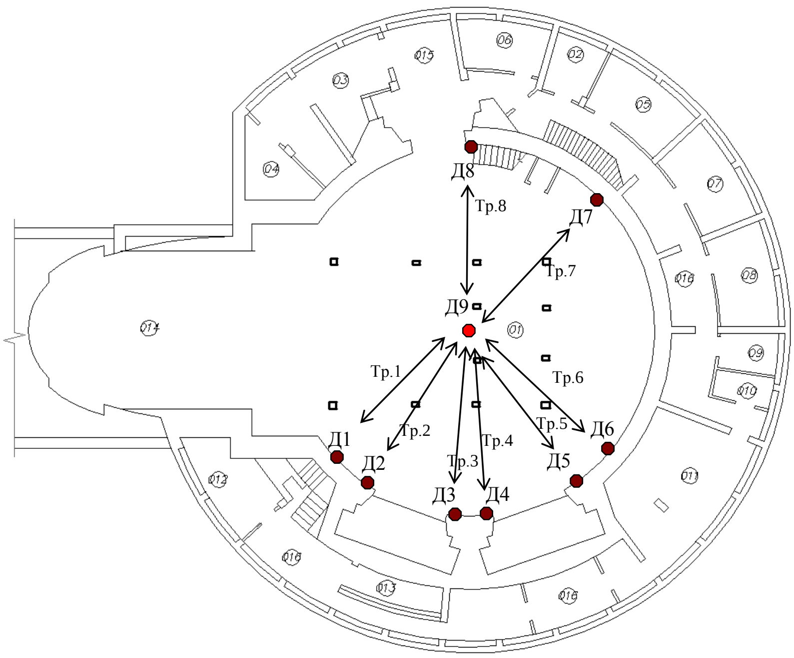


Figure 5.7. Plan of sensor installation scheme.

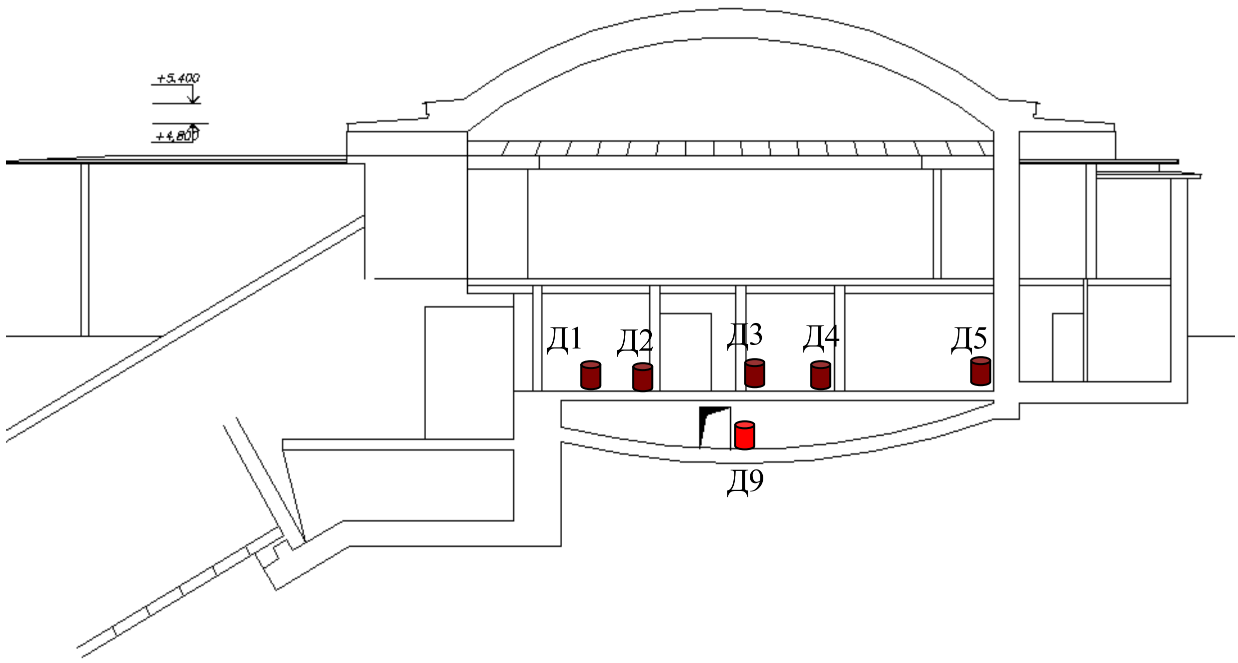


Figure 5.8. Cross-section of the lobby.

The red mark on Figure 8 represents position of central sensor installed on basement plate under machinery room with escalators.

In accordance with the submitted scheme, consistently near the D1-D5 sensors reinforced concrete structures were excited by a sledge hammer. Registration of signals was carried out in pairs for sensors D1-D9, D9-D2, D3-D9 etc. Thus obtained amplitude-time implementation subsequently analyzed using specialized software, including Fourier analysis and wavelet analysis of signals.

Seismoacoustic method allows inspection of ground, too. To determine the weak areas of ground around the perimeter of the building, in accordance with the scheme of the measurements shown in Figure 9, the excitation of seismic waves was produced in the ground with a sledge hammer weighing 8 kg and registered them with the seismic sensors installed on the ground, as well as on concrete designs of the aerial part. In accordance with the scheme of measurements signals have been received for 8 routes, whose analysis was performed using Fourier and wavelet processing.

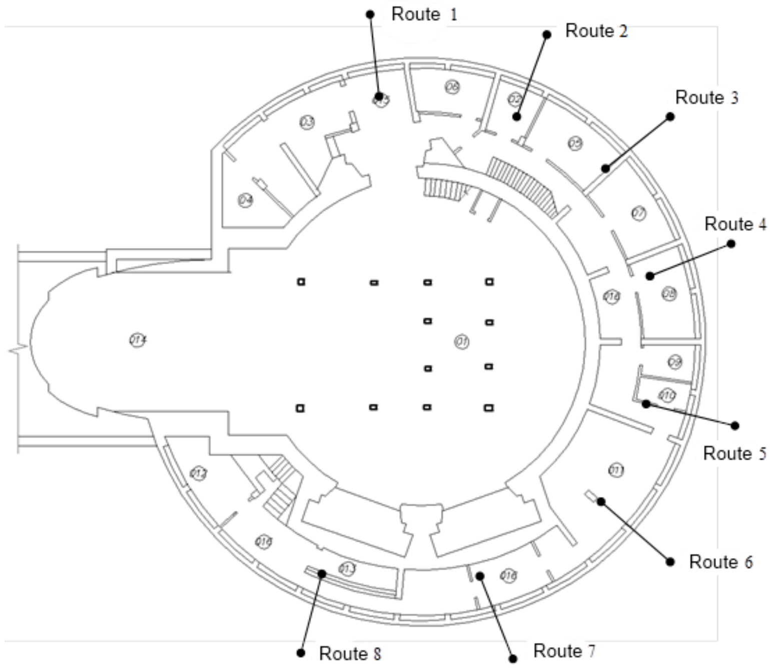


Figure 5.9. Measurement scheme for revealing weak ground areas.

Wavelet analysis of signals was performed in two frequency bands using wavelet Gaus25, Morlet, etc. To determine defects in the base plate under the machinery room basement signals were analyzed in the frequency range 1000 Hz - 22,000 Hz. To survey the state of the soil under the foundation slab signal analysis was carried out in the frequency range of 9 Hz - 300 Hz.

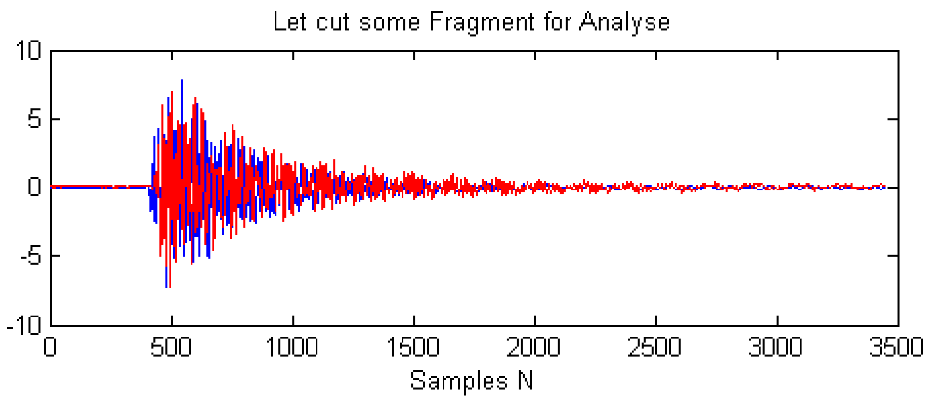


Figure 5.10. Example amplitude by time signal representation.

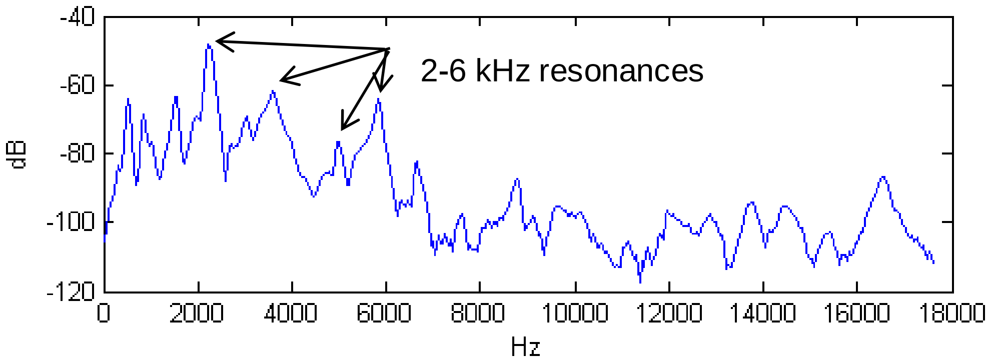


Figure 11. Fourier-spectrum of sample signal.

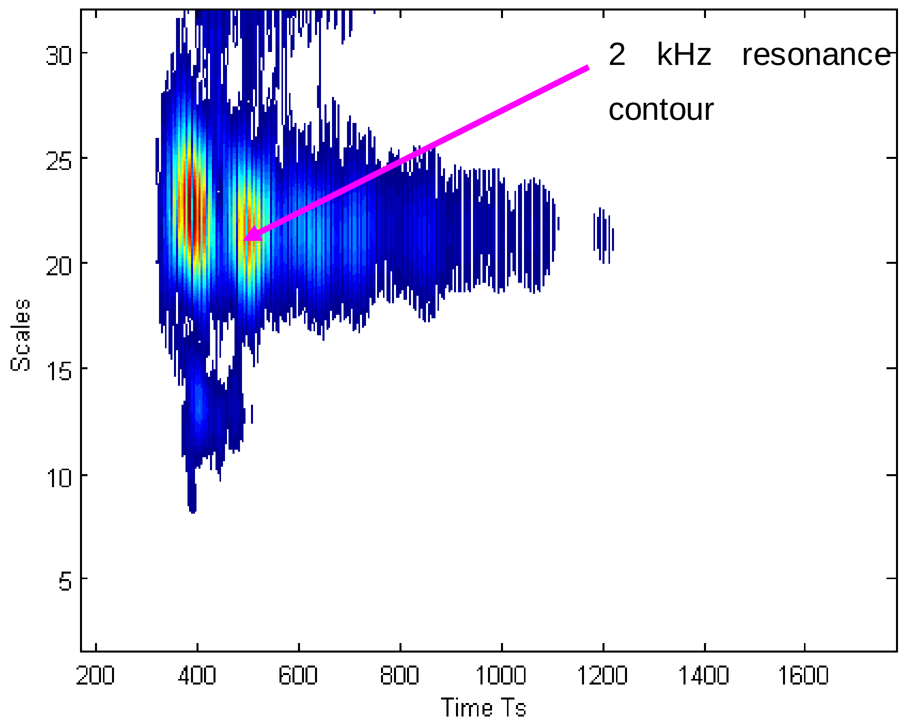


Figure 5.12. Mutual wavelet-spectrum.

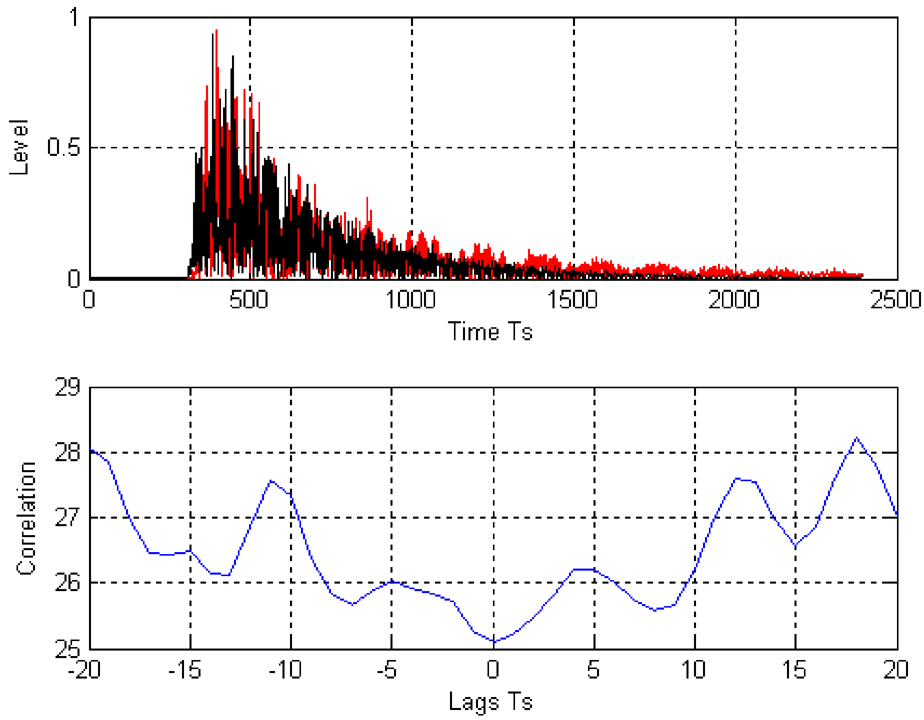


Figure 5.13. Amplitude by time representation of 22kHz signal.

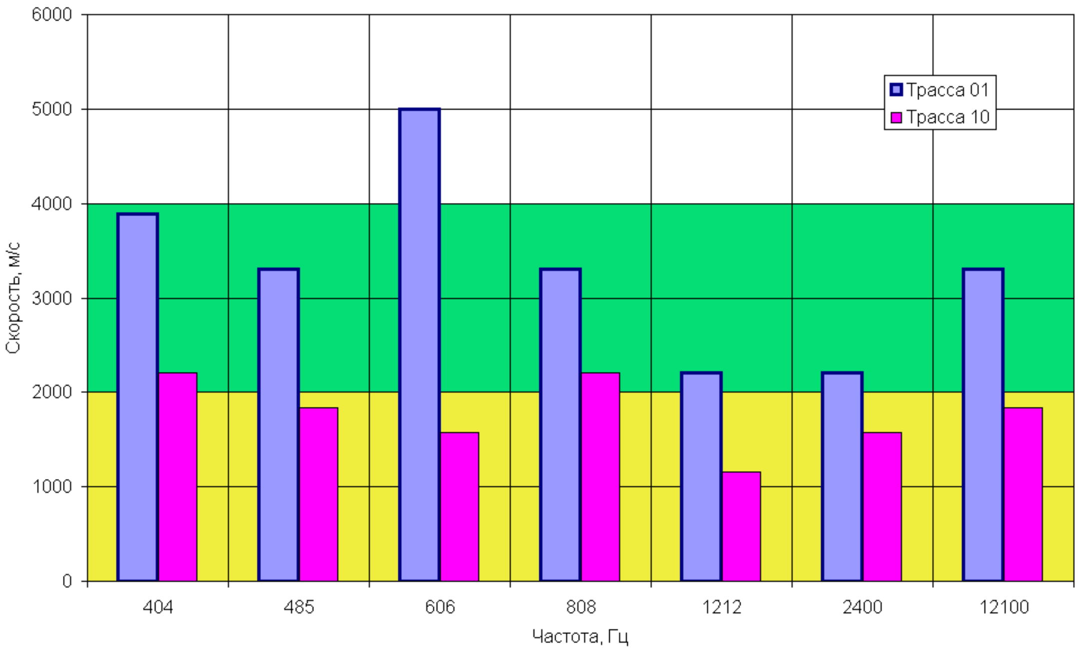


Figure 5.14. Comparison of signal speeds at various routes and frequences.

Comparison of the velocities of propagation of seismic waves was produced on routes located in similar circumstances. Green area on the charts shows normal propagation velocities for the material of construction. Yellow marked zone of lower velocity of propagation.

According to a survey of the lower joints of the state machine room has been established: In the lower part of the construction joints of the machine room, as well as construction in the joints of the lower part of the machine room and the oblique stroke (see the scheme at Figure 8), cracks were not found. However, in some points tension is close to the maximum stress state (lower wave speeds at Figure 14).

To determine weak areas of ground around the perimeter of the metro station signal analysis in different frequency bands was carried out, which allowed to build a grap of time delays for different depths of soil. Figure 15 shows plots of the time delays for different depths along the routes, in accordance with the scheme of the measurements shown in Figure 9.

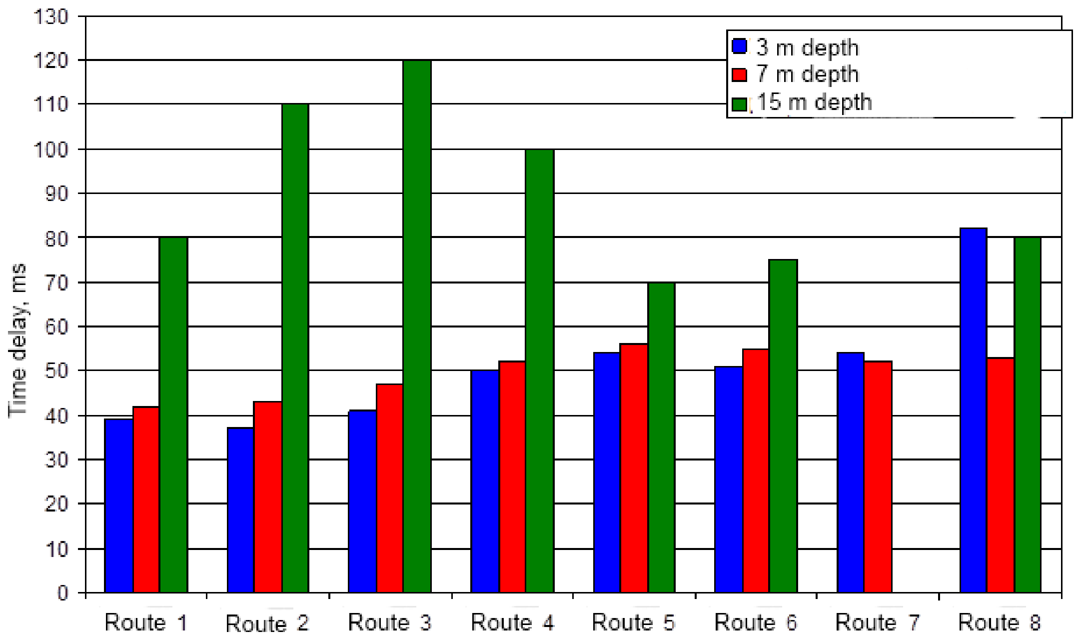


Figure 5.15. Time delays arranged by depth of the route.

Analysis of weak soils allowed to make a map of weak zones, shown at Figure 16. The map corresponds to geodetic settlements data collected during last 30 years. The green circles represent geodetic marks, red oval — the most weak concrete element.

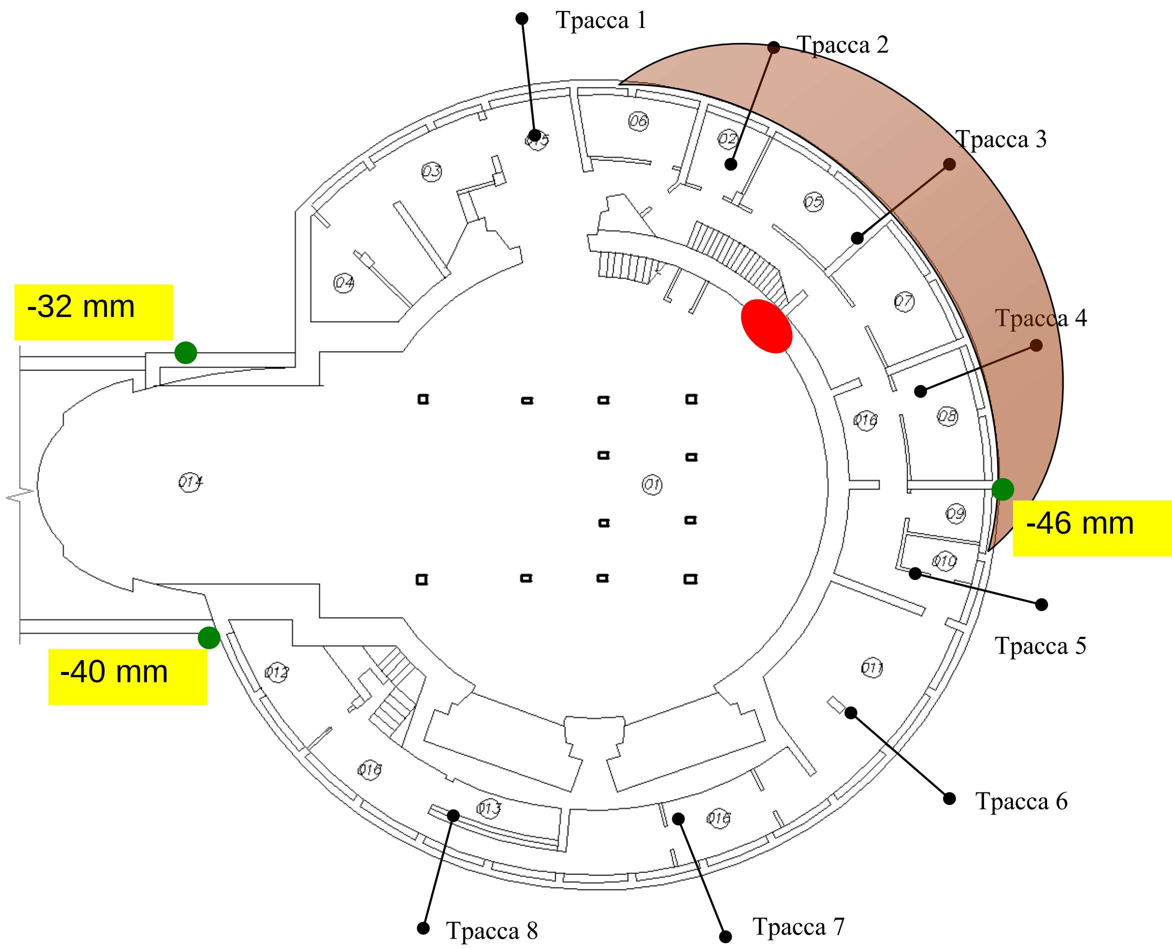


Figure 5.16. Map of weak zones.

Implementing of set of measurements made it possible to say that the building and its elements does not have critical problems, so there is no need of strengthening or reconstruction of underground part. The upper-ground part of the lobby can be constructed again using old foundation.

The same technology was used during investigation of aerotanks at Central Aeration Station. The scheme of sensor installation is shown on Figure 17.

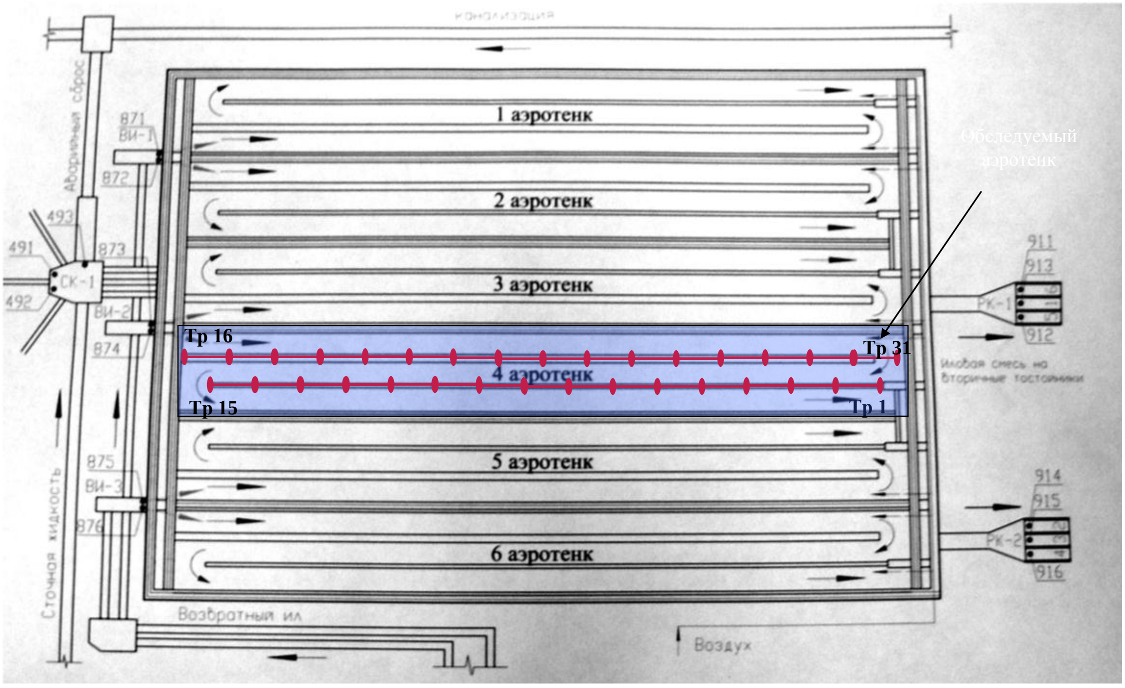
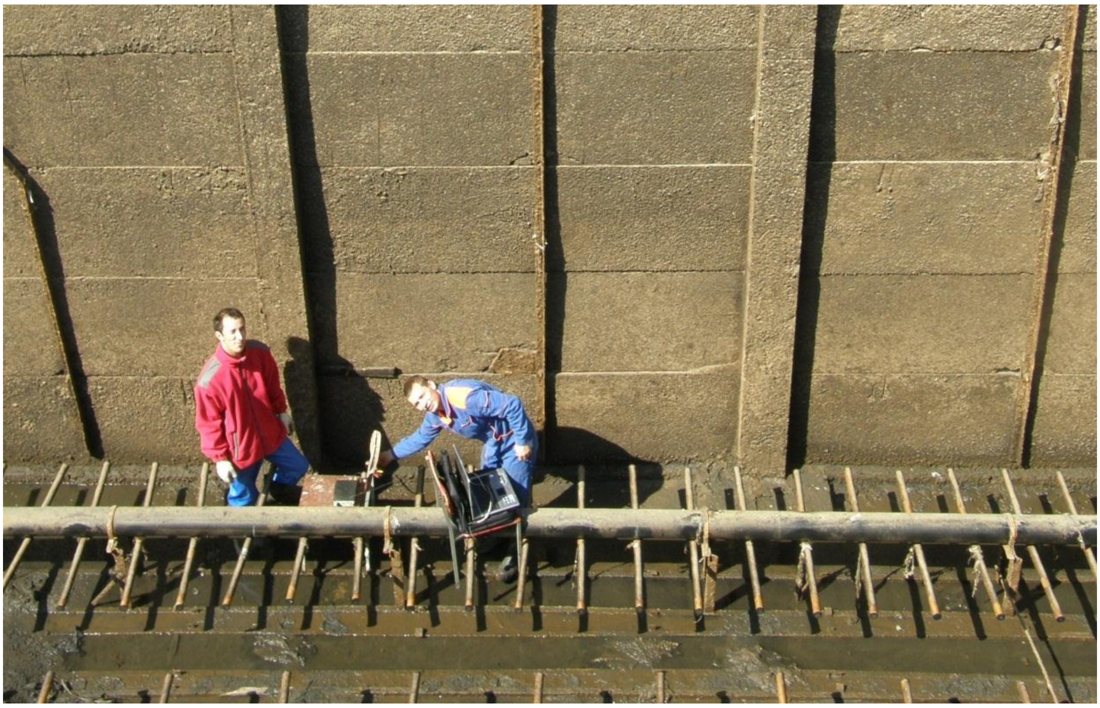


Figure 5.17. Longitudinal aerotank testing route.



Picture 5.18. Mobile measurement toolset.

5.2.4 Seismoacoustic method summary

During last 30 years, with development of calculating machines and software tools, a lot of ways to visualize signals. Using quite wide-spread software complexes, such as MathCAD with additional modules allows quick comparison of signals received in a set of measurement points.

The best results are achieved when a set of identical structures are inspected. This allows comparison of signal characteristics with the same initial conditions and gives clear information of anomalies in some areas of them, if detected.

6. ELECTRICAL EXPLORATION OF SOILS

6.1 Electrotomographycal probing method description

Two main feeding electrodes, A and B (both connected to generator), are installed in various points of area being probed. Then potential difference has to be measured using measurement electrodes M and N installed at distance of 5 metres.
Probing can be made using various distance between AB electrodes (60...150 m). Method of works was designed for the processing of submissions received using a computer program RES2DINV for tomographic geoelectrical section plotting. All measurements are carried out with SER-1 equipment (see Appendix 1 for detailed charasteristics). The magnitude of current in the supply line, depending on the grounding of AB, is typically 20-100 mA, which provides a stable measure of the potential difference ΔU between electrodes M and N. Works are carried out at frequency of 19.5 Hz.

Processing of materials for the tomographic section on profiles is performed using the computer program RES2DINV, which automatically finds the two-dimensional (2-D) model of the resistance of the medium for the data obtained by tomographic techniques (by Griffiths and Barker 1993). This program is designed for the inversion of large data sets (from 200 to 6500 points) collected by observation system with a large number of electrodes (from 25 to 1800). The program can work with the method of finite differences and finite elements for the calculation of the direct problem. This program can be used for observations with the settings Wenner, two-electrode, the dipole axis, three-electrode, Wenner - Schlumberger and equatorial dipole. In addition to the usual, the program supports non-standard installation, with an almost unlimited number of possible locations of the electrodes. As a result, a tomographic processing of two-dimensional (2-D) model of soil resistivity (in Ohm*m) is obtained.

6.2 Charge measurement method description

Electroprospecting method of charge measurement of the magnetic field is used to locate areas of water flow from the basement of a building into the surrounding soil (or vice versa). The measurements ware performed using a magnetic antenna receiver (a magnetic matching measuring device). The scheme used is shown on Figure. 6.1.

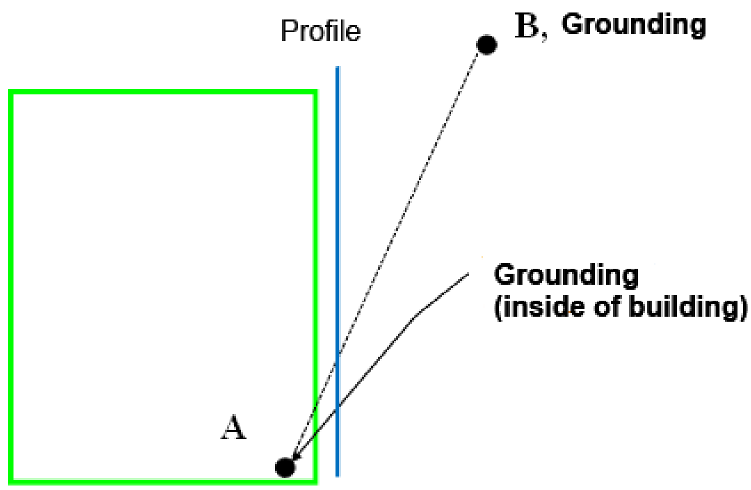


Figure 6.1. Scheme of electrode installation.

Two electrodes are grounded in and outside of a building basement. The current is applied to the electrodes with a fixed frequency of 625 Hz. With the help of a magnetic antenna of SER-1 electro probing station a set of measurements is obtained along of the profile to be inspected. In areas with high water saturation (duy to defects in hydro insulation of a basement) high current flow is and this causes rising of magnetic field strength caught and measured by magnetic antenna.

6.3 Naval Cathedral basement exploration using electric tomography method.

Using the first method of electrotomography 3 profiles were inspected (the 4th side of the cathedral borders stone-covered square, so electrode grounding was impossible) and were visualized into 3 cross-sections along sides of the cathedral. The results are shown on Figures 6.2-6.4.

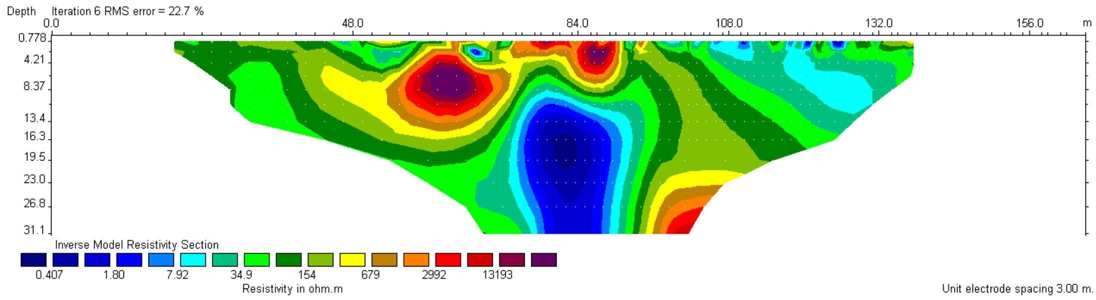


Figure 6.2. Electrotomography cross-section 1.

The first cross-section has no anomalies, found places with water presence are insignificant and correspond to a gully nearby of the cathedral.

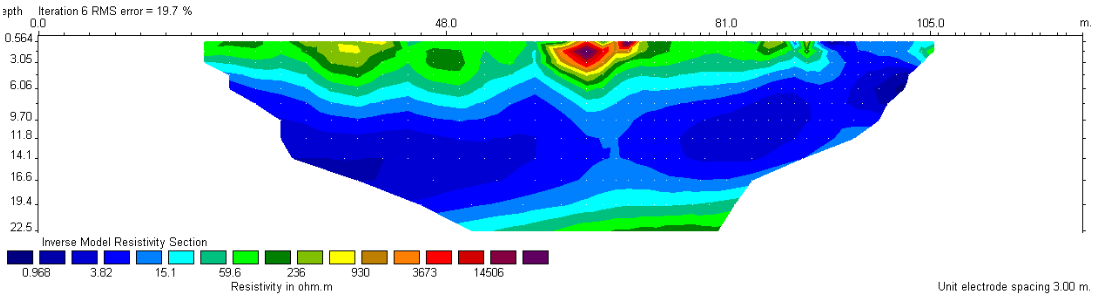


Figure 6.3. Electrotomography cross-section 2.

Three zones of high water-saturated soils were found, and the third one, at distance of 90-105 m from profile start point, influences to cathedral foundation structures.

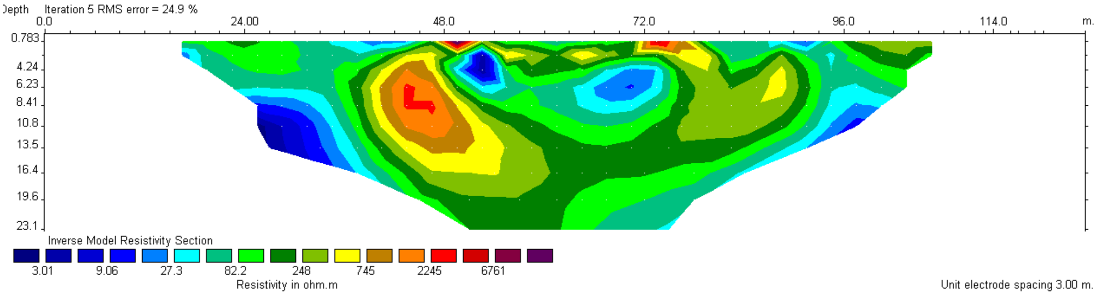


Figure 6.4. Electrotomography cross-section 3.

Figure 6.4 represents several small zones of seam inundation near ground level that can influence to the foundation.

6.4 Naval Cathedral basement exploration using charge measurement method.

Diagrams of magnetic field changes along profiles of probing are shown on Figures 6.5-6.6.

Figure 6.5. Results of charge measurement along Profile 1.

Figure 6.6. Results of charge measurement along Profile 2.

The results carried out with both methods have correlation to each other (have the same placement and type).

The summary of electrical probing is represented on Figure 6.7. According to the results the following conclusions and recommendations were carried out:

- A possible major source of ground water is rainfalls
- Inundated or weakened areas of soils that affect the design of the cathedral are formed because of the general groundwater flow in the direction of the gully, and by pumping water from the basement of the cathedral (the main reason).
- Effect of utilities (leakage) is insignificant, except sewage outlet

Based on the above the set of restoration work should probably include the following activities:

- Consolidation of the weakened areas of soil under the walls of the cathedral (downhole injection of fixing solutions)
- Restoration of the cathedral fence waterproofing to a depth of 6-8 m
- Restoration of storm water drainage system

The diagram on Figure 6.7 includes results of seismic measurements using technology described in 5.2.3.

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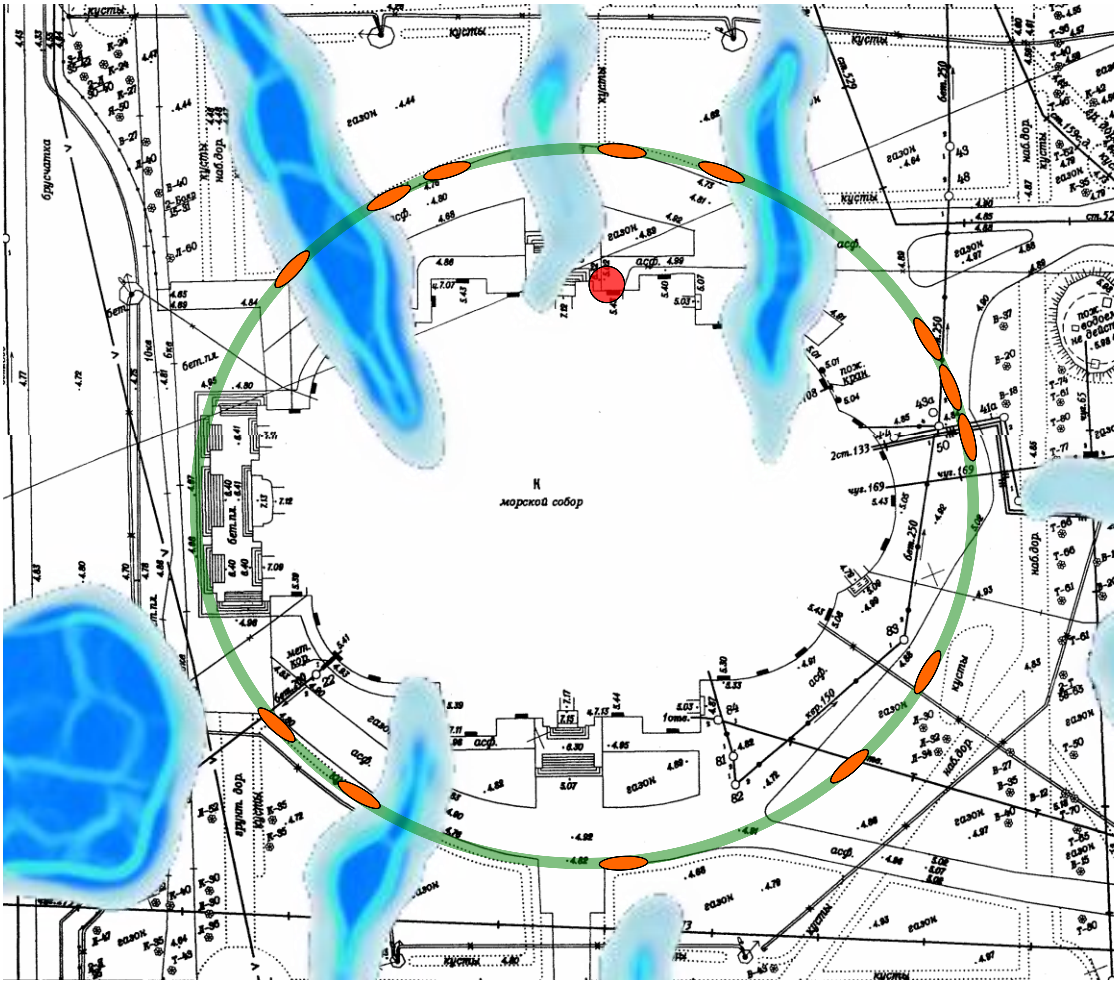

Figure 6.7. Complex diagram of weak soil areas and inundated zones.

Legend for Figure 6.7:

- The estimated location of the enclosed sheet piling

- Piling absence areas

- Cracks in foundation

- Inundated zones

7. INSPECTION OF POSSIBLE INFLUENCES ZONES

7.1 Task list of typical investigation

National codes (see 2.) require investigation of 30-m zone around of new building site or reconstruction of existing buildings. In special cases monitoring works are held to observe changes of structures condition (level of groundwater, cracks width, etc.).

Typical inspection includes:

- Photofixation of defects of load-bearing and envelope structures
- (cracks, destruction of finishing layer, etc.)
- Measuring of cracks width, length.
- Describing any other types of defects.
- Describing of foundation construction and checking calculations of basement
- Calculation and testing of load-bearing structures material (masonry/concrete)

7.2 Describing foundations

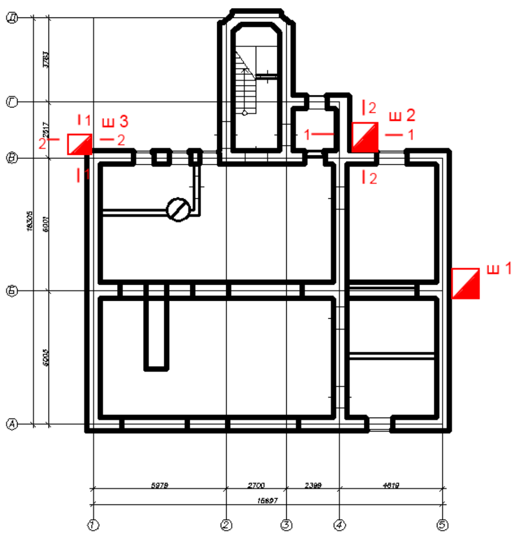

Figure 7.1. Shaft placement scheme.

This part is usually done by digging exploring shafts nearby main walls. Example plan of shafts is shown on Figure 7.1. After that the soil layers are carefully examined and samples are sent to laboratory for tests.

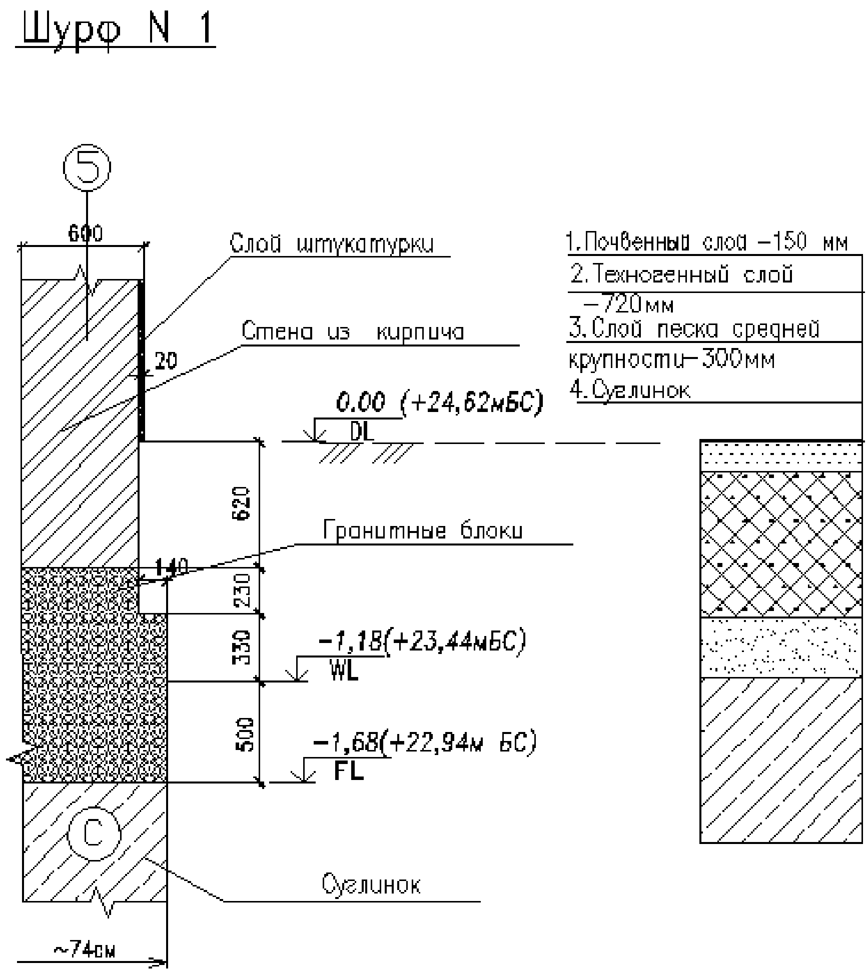

Figure 7.2. Foundation exploring result.

Figure 7.2 shows typical foundation cross-section, obtained with exploration shaft examination.

Figure 7.3. Exploration shaft.

In addition to laboratory tests, dynamic ground probe is done. This test is an immersion of the probe into the ground by a hammer. The number of hammer blows and depth of probe immersion show soil characteristics.

According to GOST 19912-2001 ("Guidelines for the dynamic light sensing probe precast") the following characteristics are to be carried out:

- angle of internal friction (φ = 15-17º)
- adhesion of the particles (c = 14-15 kPa)
- modulus of deformation (E = 10-12 MPa)

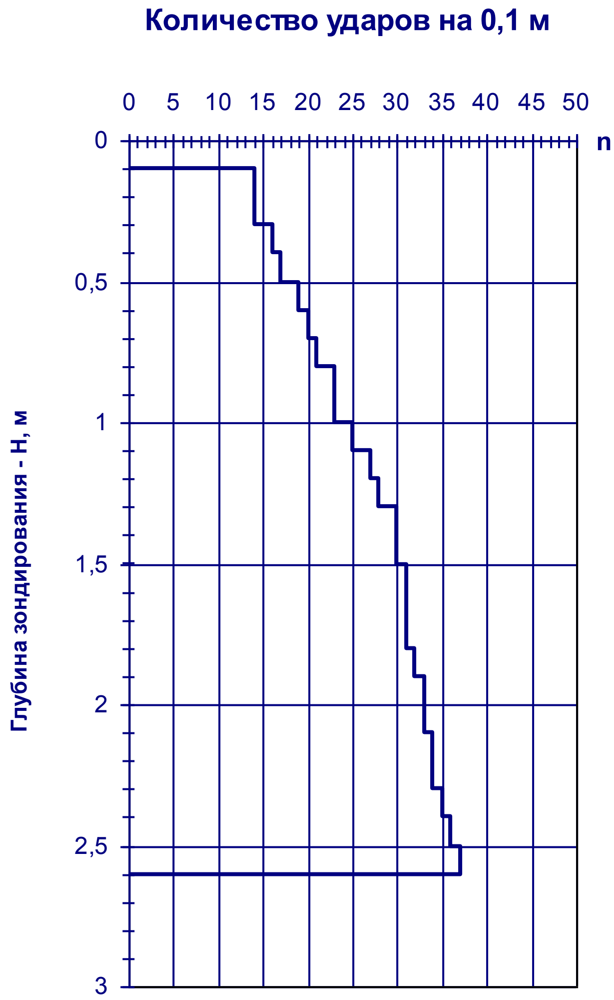

Figure 7.4. Probing graph. X-axis is number of hammer blows, Y-axis is depth of probe immersion.

7.3 Calculation and testing of load-bearing structures material

The strength characteristics of masonry walls were determined using sclerometer "Beton Control" (non-destructive testing method of the elastic rebound). Using of such devices is shown on Figure 7.5. Although this kind of test is quite inaccurate and requires special climate conditions while testing, it is widely used.

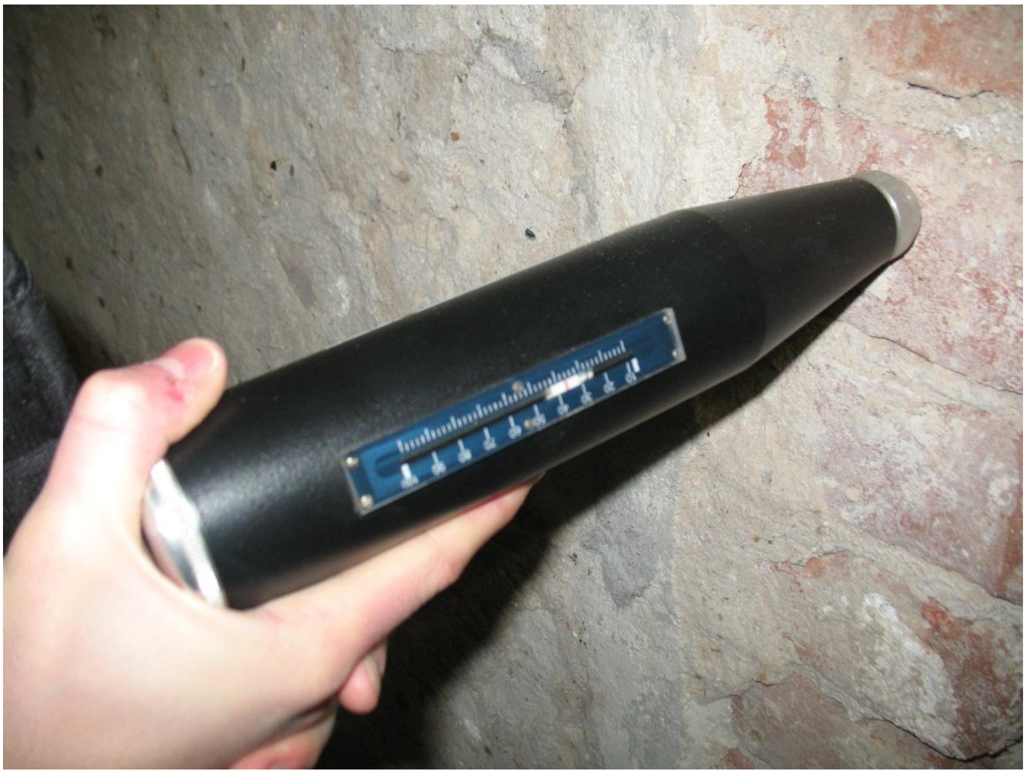

Figure 7.5. Masonry testing.

Figure 7.6. Mortar testing.

7.4 Opening of structures for examination

If possible, every floor has to be opened to check condition of its structural materials. After that the structures are represented on drawings in cross-section.

Figure 7.7. Opening of ceiling.

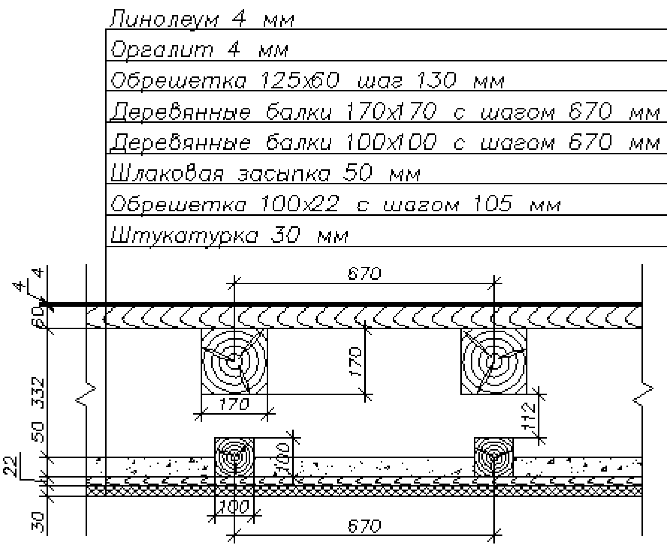

Figure 7.8. Actual drawings of structures.

7.5 Photofixation of defects

Every investigation report includes photos of defects of structures. This also helps to make recommendations and conclusions. Detailed macro-photos are usually numbered and linked to a plan of defects during the work. Figure 7.9 represents typical plan of defects.

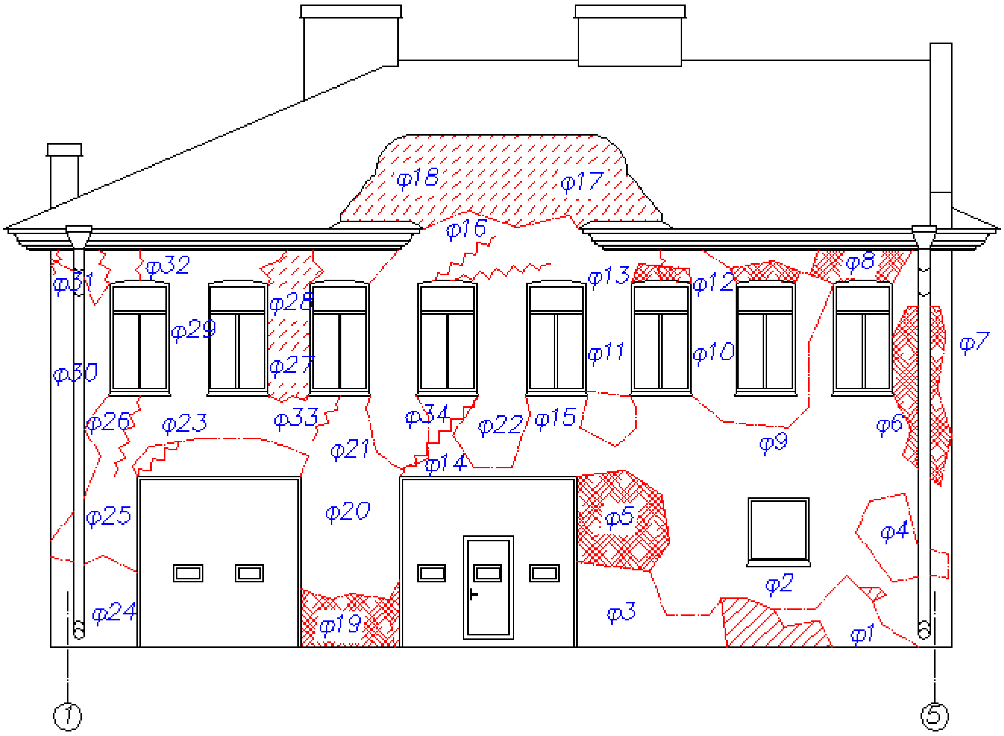

Figure 7.9. Defects plan

Final report includes tables of defects, representing its position and some characteristics (crack width, area, possible reasons, etc.)

Figure 7.10. Inclined cracks (ф23).

Figure 7.11. Mould, finishing layer destruction (ф1).

8. CONCLUSION

Nowadays the demand on investigation works increases every year. Large industrial areas are becoming new business districts, old houses are being reconstructed or renovated, and new unique buildings are being built.

The future of non-destructive investigation methods is closely related to combination of innovative theoretical ideas with practice. One of the most promising technologies of today is the laser scanning devices, that could help with at least visual inspection and dimensioning of buildings and structures. Laser devices have great resolution, that allows using reduced-scale models for stress testing, and the cost is often less than full-scale tests.

There is no doubt that Russian experience in investigation works, in collaboration with European experts in tool design, will develop this industry to a new level of evolution.

FIGURES

APPENDICES

APPENDIX 1

1 (2)

Inspection equipment complex SER-1

SER-1 is to excite and for the observation of electromagnetic fields in the work methods of electrical resistance, the charge of the natural electric field, inductive, and other methods.

The equipment is made explosion-proof with type of protection according to GOST 12.2.020-78, GOST 22782.5-78 and Ingress protection IP54 performance in accordance with GOST 14254-80.

Meter SER-1 can be used with any set of electric generators or as part of a set SER-1.

Figure 1. General view.

Technical and operational characteristics:

Case implementation	IP54
Working mode and frequency selection	Cascading menu with help of LCD. Measurement program is controlled by ADSP-2189 signal processor.
Health monitoring	Self-testing
Working frequencies	0.1 Hz – 4 kHz constant current
Memory	32 kB
Interface to PC	RS-232S
Upgrade of device functions	Any PC-compatible computer can be used as a programmer of the device.
Operating temperature range	От –10°C до +50°C
Power supply	NI-MH SAFT-1,25 accumulator set
Power consumption	working - 200 mW, idle - 0,2 mW
Generator power	5 W
Input resistance	Constant current - 10 mOhm, Variable current - 10 mOhm
Dimensions, mm	230×165×70
Weight	3.5 kg

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