# Geodetic control of the technical condition of buildings

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**Abstract.** Problems related to ensuring the control of the state of cultural heritage objects have existed for a long time. Their solution requires timely monitoring and consideration of effective algorithms for collecting and processing information. The object of the study is a building that has the status of an architectural heritage monument. The article describes the result of a study that was conducted to analyze the effectiveness of the instrumental geodetic method in assessing the technical condition of architectural heritage monuments. The research methods evaluated in the work were: determination of vertical movements of the foundation of the building and determination of the deformation characteristics of the building. Modern digital geodetic instruments were used in the implementation of this method. The purpose of the study is to analyze the application of the instrumental geodetic method as one of the main methods in assessing the technical condition of architectural heritage monuments. The instrumental geodetic method described in the article was based on empirical data obtained from direct geodetic measurements, conclusions are drawn about the technical condition of the monument. As a result of the research, it was found that the building has cracks, as well as the uneven nature of the foundation precipitation. At the end of the article, the authors were convinced of the need to use geodetic methods to assess the geometric parameters of buildings, gave recommendations for assessing the technical condition of architectural heritage monuments, and also described measures to preserve them.

## 1 Introduction

Preservation of cultural and architectural heritage is one of the most important tasks currently facing a civilized society [1-30]. Many researchers are concerned about the problem of preserving historical and cultural monuments. Their developments of researchers are presented in the works [25].

In general, the historical preservation of cultural heritage objects is associated not only with their careful operation and restoration, but also with competent management, cost estimation, considered, for example, in [22]. Currently, many researchers are studying various methods of documenting, managing and preserving cultural heritage [21; 27].

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All these processes should not only ensure their safety for future generations, but also allow us to recognize and more deeply understand our past. The preservation of architectural monuments helps us to study the architectural experience that has applied in the organization of space and design of buildings, and perhaps learn the art of using classical architectural elements in modern building practice, which is consistent with the authors' research [8]. In addition to serving as a link to the past, historic buildings also serve as overseas tourist attractions for a large portion of the world's population. Famous cultural sites such as castles, cathedrals, mosques and other public buildings celebrate the folk cultural heritage of a particular region. Visiting these places is one of the most popular activities that can be offered to people of all ages and nationalities, since the historical buildings serve as wonderful teachers of the past in their own way.

Just in the article [28], the author conducts a historical analysis of a number of museum complexes as a cultural component not only of traditionally historical features, but also as a unique system of practical research in architecture, education, enlightenment.

Thus, the study of a complex of works for the preservation of architectural monuments is an actual object of study.

There are several approaches from the least intervention to the most in dealing with historical objects - these are preservation, restoration, restoration and reconstruction. Conservation is focused on stabilizing maintenance and repairing existing historic sites. Rehabilitation recognizes the need to change or supplement the functionality of a historic property in order to continue to use it in the national economy, while maintaining the historical character of the property. Restoration keeps buildings and structures unchanged, "frozen" in a certain period of history, while removing evidence of other periods. Reconstruction allows you to recreate the disappeared or not preserved parts of the architectural heritage. Although the preservation of rich cultural resources has come a long way over time, it is important to emphasize that each region has its own unique experience in this process.

The monument restoration project is compiled for reconstruction purposes, which includes orientation to the real state, often including a 3D model. Such a model of the monument is obtained by the method of practical geodetic measurements [12].

Cultural heritage objects in accordance with the Federal Law of the Russian Federation "On objects of cultural heritage (monuments of history and culture) of the people of the Russian Federation" (dated June 25, 2002 No. 73-FL) [19] are divided into the following types: - monuments, assemblies, places of interest. According to their historical and cultural significance, they are divided into objects of federal, regional and local (municipal) significance. According to this law, cultural heritage objects can be used for administrative, residential, socio-cultural and other purposes, if it does not contradict the established requirements for ensuring their safety. In 73-FL [19], measures for the state protection of cultural heritage objects include: monitoring compliance with legislation, accounting, conducting historical and cultural expertise, punishment for damage, monitoring the development of urban planning and design documentation, coordinating land management, economic and other work in the protection objects' zone, control over the state of cultural heritage sites, etc.

A thorough study of the technical condition of architectural monuments is the starting point when deciding on their operation. The methods used to survey architectural objects are very diverse [18; 24] and are another very important part of the process that ensures their durability. A detailed survey of building structures of architectural heritage objects includes many aspects: a description of the characteristics of the building, a brief historical background; analysis of geological survey data; detailed consideration of constructive solutions for foundations, walls, ceilings, coatings, stairs; description of their defects and damages; instrumental studies - determination of structural deformations (precipitation, heels), determination of the parameters of the microclimate of premises, masonry properties, mortar characteristics, etc.; a description of all devices and instruments used in the examination is given, as, for example, the research in [17]. At the end of the survey, recommendations are made for the preservation of the cultural heritage site, its adaptation to modern use and further safe operation.

In [2], a proposal to create an integrated system for comprehensive monitoring of the technical condition of cultural heritage objects was made. An integral part of such monitoring is instrumental geodetic monitoring [20]. Geodetic methods of instrumental survey can determine the general deformations and deviations of the building from design standards [15; 23]. The use of topographic and geodetic works for the assessment and preservation of architectural monuments has a number of features, discussed in [26].

These features include:

1) the absence of topographic and geodetic materials for the area of work, or they are outdated;

2) in the process of restoration work, there is often a need for geodetic measurements under adverse weather conditions, for example, at low temperatures, which affects the performance of digital geodetic instruments.

It should be noted that one of the modern methods of instrumental geodetic survey of the technical condition of architectural heritage monuments is a remote sensing technique: the use of laser scanning, described by the authors [1; 4] in their works. This technique allows you to obtain a 3D model of the building, that is, its complete geometry and evaluate its roll, twisting, etc. 3D-modeling gives an opportunity to reconstruct the building with the help of computer graphics, can help in restoring the appearance of many monuments.

Let's consider the whole complex of geodetic methods used for the problems of preservation of architectural monuments on the example of determining the state of the geometric parameters of the theater building, which is a monument of architectural heritage of regional significance.

## 2 Materials and Methods

The purpose of the study is to analyze the application of the instrumental geodetic method as one of the main methods in assessing the technical condition of architectural heritage monuments.

The following tasks were set to achieve the purpose of the study were set:

1) to study the features of assessing the technical condition of architectural heritage monuments

2) to investigate the technical condition of the architectural monument of regional significance and draw a conclusion about its condition

3) based on empirical data, perform an analysis of the applied geodetic method

4) give recommendations on the assessment of the technical condition of architectural heritage monuments

5) develop recommendations for the optimal application of the methodology for assessing the technical condition of architectural monuments.

Specialists often encounter complex cases of deformations and destruction of load - bearing structures when examining the technical condition of buildings of architectural monuments specialists. First of all, this is due to the fact that such structures for many years of their existence have experienced the action of many factors that negatively affected the technical condition of the structures. Frosty destruction of masonry, deformation of the foundation soils, metal corrosion, mechanical damage and loss of whole elements can not only distort, but also fundamentally change the initial structural scheme of the building.

The technical condition of buildings and structures is determined by several groups of parameters, the most important of which is a group of geometric characteristics.
The most significant geometric characteristics for the technical condition of buildings are deformation.

Let's distinguish two groups of geometric parameters, the first of which characterizes the spatial position of the entire building in the topocentric coordinate system, the second – the relative location of its building elements.

There are two main methods for examining damage to buildings and structures: visual and instrumental. During a visual inspection, flaws and defects visible to the naked eye revealed: cracks, chips, deviations from design solutions, violation of the geometry of the building, etc.

There are measuring instruments that are used when performing visual examinations: tape measure, tape, ruler, caliper, depth gauge, and in addition, digital photography has been widely used recently. The use of modern digital photogrammetric systems in this case greatly simplifies the survey process, allows for an objective assessment of the destruction of the surface of monuments and additionally provides a high-resolution virtual 3D model that allows further investigation of the object [6].

At the same stage, monitoring of the development of cracks and faults is organized. The value of disclosure is assessed visually or by measurement. The dynamics of deformation is judged by the development of cracks.

The disadvantage of this method of assessing the technical condition of buildings or structures is:
- lack of a complete picture of the geometry of the building;
- only an approximate idea of the technical condition of the building is formed.

The instrumental method is destructive and non-destructive. In the first method, we had to damage the building by cutting material samples out of it.
In turn, the survey of architectural monuments consists in assessing the technical condition of such buildings using the most sparing and non-destructive methods. The instrumental geodetic method is just one of such methods.
The main tasks solved using this method are:
1. Determination of the real deformed state of the building.
2. Determination of the factors influencing the change in the stress-strain state of the building.
3. Development of recommendations and measures to restore the operational reliability of the building and eliminate or reduce the impact of negative factors.
The complete geometry of the building must be determined in order to solve the tasks described above during the survey of the building.

At the same time, using the instrumental geodetic method of assessment, we will determine:
- local deformations of the Earth's surface of the area where the structure (building) is located: vertical and horizontal movements;
- parameters of spatial geometry and deformations of the internal geometry of buildings and structures: precipitation of foundations, rolls and distortions, twisting (twisting) of the structure as a whole or its parts, etc.

This is the reason for the choice of the research methodology to achieve the research goal, as well as the density of urban development and vibration from traffic.
The methodological basis of the research is the empirical method.
As an empirical research material, the results of the survey of an architectural monument of regional significance (theater building) by the geodetic method are accepted in the work.

Only one approach was used in the work: the use of an instrumental geodetic method using a digital level and an electronic total station, but there are other geodetic methods (for example, using laser scanning) that were not considered.

# 3 Results

A network of geotechnical monitoring (ground reference points, sedimentary grades) must be created for reliable information about deformations of structures at the facility.
We agree with the authors [5] that the geodetic network (geotechnical monitoring network) forms the basic framework with which all further geodetic measurements are connected, and that is why it was created with the highest achievable level of accuracy.

The internal geometry of the building is characterized by: absolute, uniform and uneven precipitation of the studied points of the structure: the angles of twisting of the edges of the structure and its individual parts; the angle of mutual torsion of parts of the structure relative to each other; absolute (relative) conditional compression of walls, distortions of building structures, radii of curvature of the bent section.

When studying the geodetic method of assessing the technical condition of architectural heritage monuments, full-scale measurements were carried out to determine the deformation characteristics of the theater building using modern digital devices: the draft of the foundation, the rolls of its edges and the rolls of the planes of the walls according to the specified sections.

Work on the assessment of the technical condition of the object under study was started in 2010 and was interrupted for 10 years.
In this work, the results of archival measurements of 2010 were used in the analysis of its condition at this time and the applied geodetic method.

## 3.1 Determination of vertical movements of the building foundation

The measurement of the sediment of structures consists in the periodic determination of the heights of the points fixed on the structure under study in relation to the initial reference points securely fixed on the ground and taken as fixed. From the comparison of the heights of the points on the structure, conclusions are drawn about the magnitude and speed of the precipitation of the structure.

In a geometric sense, the sediment is expressed by the values of vertical segments lowered from the initial to the subsequent position of the sedimentary mark. In cases where these segments for different brands are equal, precipitation is called uniform, and accordingly, when the segments are not equal, uneven. The principle of processing repeated measurements is that there are differences in the marks of sedimentary marks between measurement cycles.

We performed a survey of the existing sedimentary marks laid in 2010 to determine the vertical movements (settlement) of the foundation.
Survey and analysis results:
1. 37 marks have been preserved, which are not enough to perform high-quality instrumental observations
2. We laid nine additional sedimentary marks (reinforcing pin with a diameter of 10 mm and a length of 200 mm)

We used a second-order leveling technique to determine the elevations of the sedimentary marks. We carried out leveling in accordance with regulatory documents from the points of the urban high-rise geodetic network and a temporary benchmark, which was additionally laid to ensure the required measurement accuracy.

The measurements were carried out in the Baltic system of heights, using the method of geometric leveling, in the forward and backward directions using a Trimble DINI 12 digital level and one-sided coded leveling staffs. The average length of the sighting beam was allowed to be 25 - 30 m along the main passages and 2 - 20 m when leveling sedimentary marks. Compliance with these conditions made it possible to reduce the observation time at the station, as well as to improve the reliability and quality of measurements.
The graphical of sedimentary marks and benchmarks, as well as leveling moves are shown in Fig.1.

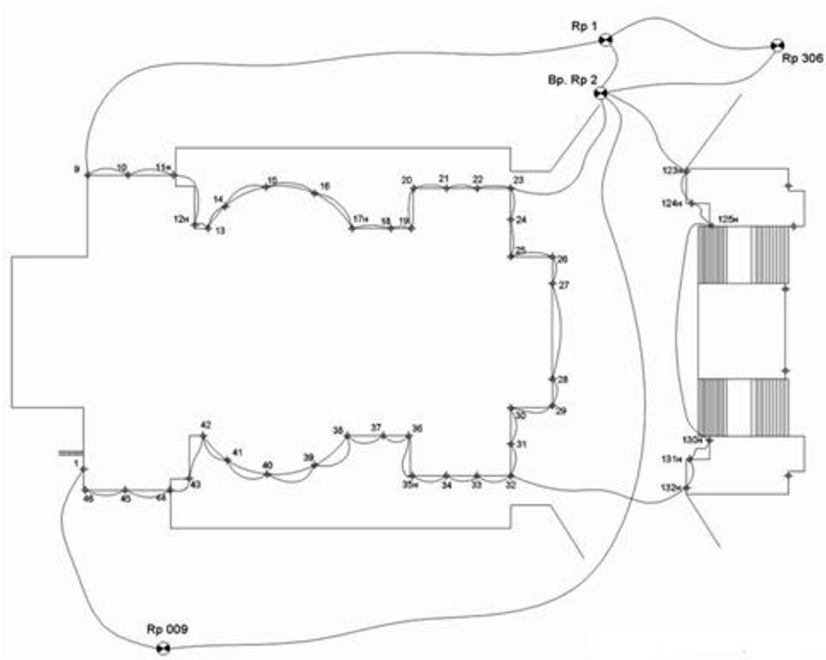


**Fig. 1.** The graphical of location and leveling of sedimentary marks
*Source*: [Compiled by the authors].

As a result of the leveling work performed, the per-cycle and cumulative vertical displacements of sedimentary marks were determined (Table 1).
The lines of equal settlement of the foundation showed graphically in Figure 2.

**Table 1.** Settlement marks leveling sheet

| № of marks | Cycle 1 18.02.10 | Cycle 11 | 17.10. 12г. | Cycle (1) 12 | 30.07.2020г. | | Cycle (2) 13 | 7.09.2020 г. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H, m | H, m | S1, mm | H, m | S2, mm | S1, mm | H, m | S3, mm | S2, mm | S1, mm |
| 1 | 70,951 | 70,947 | -4,0 | 70,9472 | 0,2 | -3,8 | 70,9474 | 0,5 | 0,3 | -3,6 |
| 9 | | 70,884 | | 70,8711 | -12,9 | | 70,8701 | 0,4 | -13,9 | |
| 10 | 70,949 | 70,944 | -5,0 | 70,9353 | -8,7 | -13,7 | 70,9344 | 0,5 | -9,6 | -14,6 |
| 11н | | | | 70,9446 | | | 70,9434 | -0,2 | | |
| 12н | | | | 72,1919 | | | 72,1910 | -0,3 | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 72,174 | 72,166 | -8,0 | 72,1602 | -5,8 | -13,8 | 72,1584 | -0,8 | -7,6 | -15,6 |
| 14 | 72,151 | 72,143 | -8,0 | 72,1359 | -7,1 | -15,1 | 72,1352 | 0,6 | -7,8 | -15,8 |
| 15 | 72,155 | 72,148 | -7,0 | 72,1411 | -6,9 | -13,9 | 72,1405 | 0,3 | -7,5 | -14,5 |
| 16 | 72,168 | 72,162 | -6,0 | 72,1550 | -7,0 | -13,0 | 72,1539 | -0,4 | -8,1 | -14,1 |
| ……. | | | | | | | | | | |
| 45 | 70,957 | 70,954 | -3,0 | 70,9544 | 0,4 | -2,6 | 70,9539 | 0,4 | -0,1 | -3,1 |
| 46 | 70,946 | 70,943 | -3,0 | 70,9422 | -0,8 | -3,8 | 70,9418 | 0,3 | -1,2 | -4,2 |
| 124н | | 72,037 | | 72,0337 | -3,3 | | 72,0313 | -0,1 | -5,7 | |

Note: S1 is the sediment since the start of observations in 2010; S2 is the sediment since the start of observations in 2012; S3 – draft between adjacent cycles of observations.
*Source*: [Compiled by the authors].

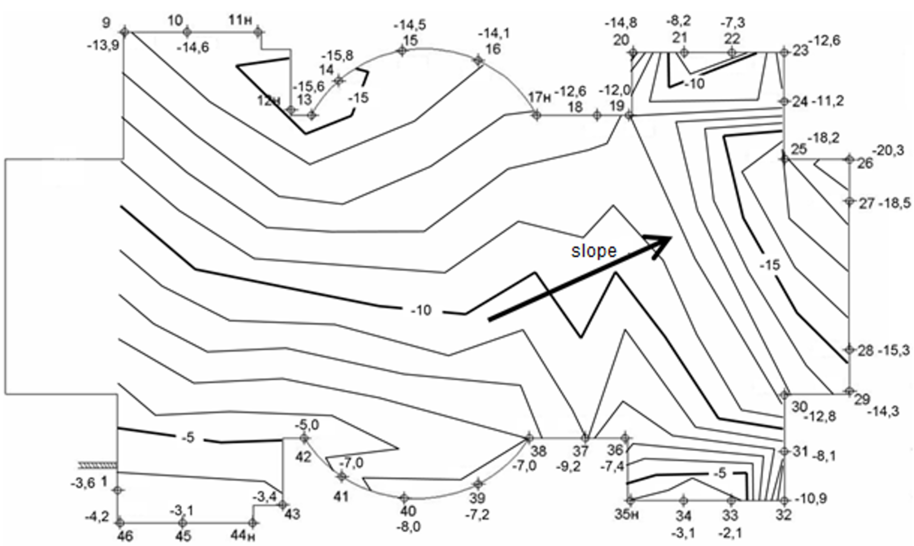


**Fig. 2.** The lines of equal settlement of the foundation
*Source*: [Compiled by the authors].

In-house processing of field measurements was performed immediately after the end of the next observation cycle. The obtained results were processed in specialized software, the actual accuracy was evaluated and compared with the set one, as a result, the marks of sedimentary marks were calculated and equalized, according to the difference of the same-named marks (points) of the deformation network, vertical displacements were determined and compared with acceptable ones. During calculations, rounding was performed to the following values: excess at one station – 0.01 mm, excess between permanent signs – 0.01 mm, marks and reference marks – 0.01 mm, draft marks and reference marks – 0.1 mm. The difference between the forward and reverse strokes did not exceed $\pm 0.5 \sqrt{n}$ (mm).

The software used at the work site solved the following tasks: strict equalization of measurement results; drawing up drawings and diagrams (AutoCAD Civil 3D – working with drawings; Trimble Business Center – a program for importing data from a total station in various formats and coordinates from text files, CREDO LEVELING - a program for processing leveling data).

### 3.2 Determination of the deformation characteristics of the building

In addition to the sediment grades, to assess the technical condition (TC) of the building, its current geometric characteristics were determined, the analysis of which provides an increase in the objectivity of the assessment of the TC. The control of the geometric parameters of the building was carried out by the coordinate method.

We applied the following implementation steps in this method:

1. We made a choice of a spatial coordinate system in which the geometric characteristics of the object under study are determined.
2. We determined the position of discretely distributed points that have the highest information content for describing the geometric parameters of the object.
3. We determined the coordinates of the studied points located in the characteristic places of the building. To do this, the Trimble 3602 DR total station on a tripod was installed from the surveyed building at a distance approximately equal to its height. The device was oriented parallel to the controlled plane (building wall). The control of the building geometry was carried out from 11 stations of the instrument.
4. We analyzed the obtained coordinates of the points and determined the geometric characteristics of the object under study - the rolls of its ribs and the rolls of the wall planes along the given sections.
5. The roll value should not exceed the value equal to 0.005*H. With a height of the investigated building of 40 m, the value of the allowable roll of the building was 200 mm.

We used the rule of digitizing the edges of the building under study when performing field work and processing the data obtained, shown in Fig. 3.

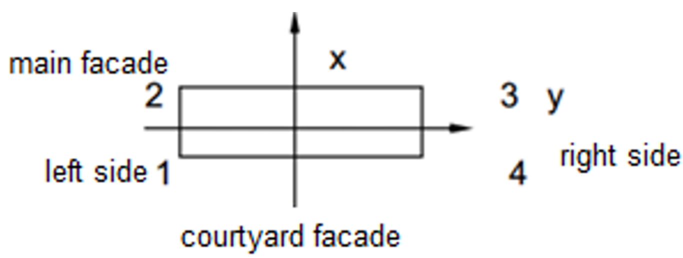


**Fig. 3.** Digitization of building edges
Source: [Compiled by the authors].

Due to the complex shape of the studied monument of architectural heritage, partial rolls were identified at different heights of its main building elements.

*Processing of building roll measurement results*
Uneven precipitation of the foundation of the building is the reason for the change in its spatial position. Roll is the deviation of vertically oriented building structures from a vertical line.

During the examination of the building, the rolls of its edges and the rolls of the planes of the walls were determined according to the specified sections.

In accordance with regulatory documents, the maximum errors of roll measurement, depending on the height H of the observed object, should not exceed 0.0001 ×N for civil buildings and structures.

In our case, the maximum error of roll measurement is 3.9 mm.

This measurement accuracy is ensured by the device used (Trimble 3602 DR electronic total station).

*Control of the shape of the wall surfaces.*

The rolls of the wall planes along the specified sections are determined by the coordinate method, the polar serif method using the Trimble 3602 DR electronic total station. Deviations of the planes of the walls were determined by control points coinciding with the specified horizons of the building, according to a regular grid (see Fig. 4).

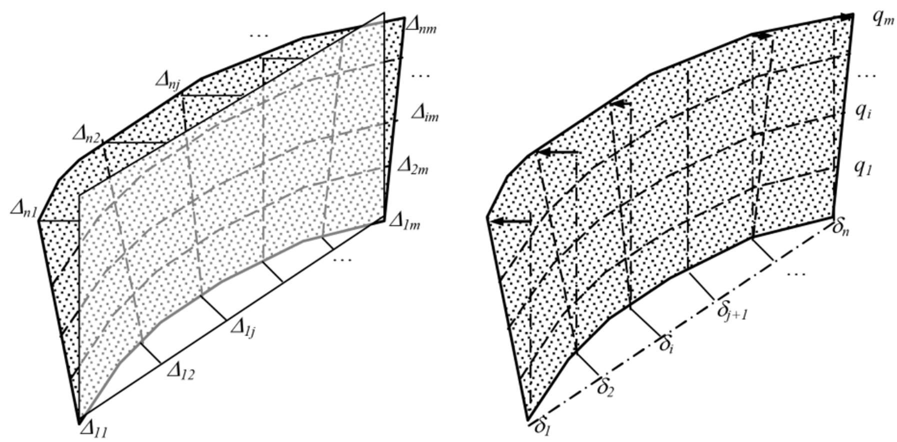


**Fig. 4.** The scheme of deviations of the wall from the vertically oriented plane

Based on the analysis of visual and instrumental examinations, the following conclusions were drawn:

1. A visual inspection of the building showed the presence of cracks in the western part of the building.
2. Based on the results of leveling sedimentary marks, it was found that the building has an uneven foundation settlement and settles to the southeast.
3. The greatest values of the total settlement of the foundation were observed on the eastern side of the building.
4. Analyzing the magnitude and direction of the rolls of the building, we concluded that the most of the recorded rolls of the building are directed outward, which indicates the presence of buckling deformation. All fixed rolls of the building do not exceed the allowable value of 200 mm.
5. The results of observations of the building rolls (their magnitude and direction) correlate with the results of observations of the foundation sediment and are confirmation that the building settles unevenly and the greatest precipitation is recorded from the side of the main facade.
6. The straightness control of the extended sections of the building revealed that the eastern side of the building has a horizontal displacement of about 20 mm towards the right facade.

In conclusion, it should be noted that:

1) subsequent monitoring of the technical condition of the theater building is recommended to be carried out cyclically at least twice a year;
2) observe the opening of cracks in the walls of the building at least once every six months;
3) observe the geological conditions of the work area in order to exclude subsidence of the soil or flooding of the foundation of the building

## 4 Discussion

Assessment of the technical condition of architectural and cultural heritage monuments is a complex process that geotechnical monitoring is engaged in. Geotechnical monitoring [9] provides a comprehensive study of the foundation and aboveground structures of the building and includes such studies as: visual inspection, vibrodynamic analysis, instrumental geodetic monitoring, geophysical measurements and others. Timely implementation of geotechnical monitoring allows to prevent irreversible processes occurring in the soil base of the monument, as well as its foundation and structures, based on the analysis of the obtained research results. One of these processes that lead to a violation of the reliability of the entire building-foundation-ground foundation system is an increase in soil moisture at the base of buildings, as well as deterioration of the waterproofing layer between the foundation and the wall as a result of the movement of water in the soil.

The theoretical and experimental studies carried out by us allow us to conclude that in this and a number of other cases, when the factors affecting the technical condition of the building are random and numerous, it is more expedient to carry out experimental studies, based on the results of which to make recommendations and take measures to preserve them. Our findings show similarities with the results and conclusions of the studies of N. Kholovoy and R. Abdullaev [10].

Our research has shown that monitoring of the technical condition of architectural and cultural heritage monuments should be carried out with a certain frequency, without taking long breaks, as in our case, when a break between surveys of the technical condition of the theater building in 10 years led to a violation of the basic geodetic network (several stamps were lost). Such interruptions affect not only the accuracy and reliability of the obtained results of geodetic monitoring of the building, but also affect the measures for their restoration or reconstruction, which is confirmed by the research of the authors [13]. This is especially true for instrumental geodetic measurements, in which it is necessary to ensure the accuracy and measurement methodology specified by regulatory documents.

As the analysis showed, the instrumental geodetic method used in the presented study in assessing the technical condition of architectural heritage monuments is sufficiently studied, only the means used in this case differ [14; 29].

Thus, in the work of the author [16], the results of geometric leveling with the DiNi 12 digital level using invar rails are considered (the average square error per 1 km of double stroke did not exceed 0.3 mm), which does not contradict our results with a level of the same brand, but with one-sided code rails.

In general, the results of the study showed very good measurement accuracy and confirmed the results of the authors in the article [7]. The results obtained could be used to create facade models, as in [30].

It should be noted that when considering the results of the work, we propose using complex methods for the inspection of architectural heritage monuments: instrumental [20], 3-d modeling [24], as well as using automated monitoring systems [11] for operational numerical evaluation of the reliable stress-strain state of structures operating in a periodic or constant mode.

## 5 Conclusion

In conclusion of the article we note the results obtained:

1. The geotechnical monitoring network was surveyed and its new points were laid.
2. Levelling of sedimentary marks along the perimeter of the surveyed object was performed.
3. The rolls of the theater building were determined.

4. As a result of the analysis of the work performed, we were convinced that the assessment of the technical condition of an architectural monument is impossible without the use of geodetic methods.
5. The use of an instrumental survey method allows obtaining more accurate data on building structures and elements of a cultural heritage site.
6. Control of the geometric parameters of the building allows you to make a more detailed conclusion about the state of the object with numerical characteristics. This, in turn, will help to develop more effective measures to eliminate the emerging negative factors leading to the deterioration of the state of architectural monuments and its safety in general.
7. Opportunities for further research include the detailed development of a methodology designed to survey cultural heritage sites in difficult observation conditions (mountainous terrain, built-up area, vibrations, etc.).

We will develop general recommendations for assessing the technical condition of architectural heritage monuments and their preservation, based on the results of the study, as well as analyzing the work of the authors [3; 22] on ways to preserve architectural monuments to improve their design parameters:

1) apply non-destructive methods of assessing the technical condition of the building in order to preserve its integrity as much as possible and the original appearance;
2) comply with modern safety requirements when restoring the monument;
3) during a visual inspection of the building, determine the monitoring mode: urgent or regular. Depending on this, develop further measures and collect data;
4) use complex methods in the survey: visual and instrumental geodetic. Such an integrated approach allows you to get a complete picture of the condition of the building: a real digital model of the building, data on the geological conditions of the work area, operational conditions, sanitary and hygienic condition of the premises and the surrounding area;
5) use modern digital geodetic instruments in the survey of buildings, allowing you to automate the measurement process and determine the complete geometry of the building.

The research objectives were implemented.

The practical significance of the study is characterized by the fact that its result will allow using the proposed recommendations in the existing problem of preserving monuments of the architectural heritage of the region. The obtained materials of the work can be used for further scientific research.

## References

1. Adamopoulos E., Rinaudo F. (2021) Close-Range Sensing and Data Fusion for Built Heritage Inspection and Monitoring – A Review. Remote Sensing, **13(19):** 1-32. doi:10.3390/rs13193936.
2. Akristiniy V. A. (2019) The monitoring of technical condition of cultural heritage objects. In: E3S Web of Conferences. Topical Problems of Architecture, Civil Engineering and Environmental Economics. EDP Sciences, Moscow, Russia, 91: 9.
3. Babkina K.A., Kalugina E.I. (2019) Restoration methods for cultural heritage objects. Modern technologies in construction. Theory and practice. 1:111-116.
4. Badenko V.L., Lytkin S.A., Lipatova A.A., Samsonova V.M. (2018) Information modeling of cultural heritage buildings using the laser scanning method. In: SPbPU Science Week. Materials of scientific conference with international participation. Institute of Civil Engineering. St. Petersburg, Russia, november 2018 p 25-127.
5. Baran, Michal; Zuzik, Jozef, PhD. (2013) Establishing geodetic network for the restoration of a historic building. In: International Multidisciplinary Scientific

GeoConference: SGEM; Sofia: Surveying Geology & Mining Ecology Management (SGEM) 2:159-166.

6. Boochs F., Huxhagen U., Kraus K. (2008) Potential of high-precision measuring techniques for the monitoring of surfaces from heritage objects. Int. Workshop In-situ Monitoring of Monumental Surfaces, SWM08. Florence, Italy. 2008.
7. Gayrabekov I.G. Pimshin I.Yu. Gayrabekov M-B.I., Gayrabekova.I. Shamsudinova K.S. Gagaeva Kh.R. Geodetic observations of the technical condition of the engineering structure. In: Horizons of Science: Materials Science and Metallurgy Grozny, Russia 2019, p 187-195
8. Gnezdilov D.V., Kapnina E.V., Martynyuk E.S. (2019). The problem of preservation, restoration and reconstruction of the world architectural heritage. In: IOP Conference Series: Materials Science and Engineering (eds) Proceedings of the International Scientific Conference on Construction and Architecture: Theory and Practice for the Innovation Development (CATPID), Rostov-on-Don, Russia, 2019.
9. Gryaznova E. (2019) Ensuring safe operation of buildings and structures In: E3S Web of Conferences. – EDP Sciences, Moscow, Russia, 97.
10. Kholova N., Abdullaev R. (2021) Censuring the durability of foundations of buildings and structures. IOP Conference Series: Earth and Environmental Science. – IOP Publishing, Krasnoyarsk, Russia, June 2021, vol 5.
11. Korgin A. V., Ermakov V. A., (2012) Automation of the formation and correction of calculation models in monitoring the technical condition of buildings and structures. Internet Bulletin of VolgGASU. 3(23):35-35.
12. Labant S., Baran M., Zuzik J. (2016) Geodetic survey of the historic building and creating of a 3d model for the project purposes of the monument restoration. In: 16th International Multidisciplinary Scientific GeoConference SGEM 2016. Albena, bulgaria, July 2016, p 329-336.
13. Levoy M. et al. (2000) The digital Michelangelo project: 3D scanning of large statues. Proceedings of the 27th annual conference on Computer graphics and interactive techniques. Moscow, Russia p 131-144.
14. Markiewicz, J., Tobiasz, A. (2019) Review of surveying devices for structural health monitoring of cultural heritage buildings. In: Abstracts of 12th International Conference on Developments in eSystems Engineering, Kazan, Russia, 7-10 October 2019.
15. Mullodzhanova G.M., Isakov E.Kh (2022) Features of geodetic methods of monitoring monuments of architecture. J Economy and society. 6-2 (97): 597-602.
16. Novoselov D.B. (2013) High-precision leveling by a digital leveler in low light conditions. J Geodesy and Cartography. 8:14-17. – ISSN 0016-7126
17. Orlov A.S., Rubtsova E.G., Shcheglov A.S. (2021) Estimation of the load-carrying capacity of the constructions of the cultural heritage object "the oldenburg's complex. lovers bridge. 1900. Scientific journal of construction and architecture. 3(63):123-126. DOI: 10.36622/VSTU.2021.63.3.012.
18. Petrovich D. (2021) Geodetic methods for documenting and modelling cultural heritage objects. International Journal of Architectural Heritage 15(6):885-896.
19. Russian Federation (2002) Federal Law of the Russian Federation "On objects of cultural heritage (monuments of history and culture) of the people of the Russian Federation", No 73-FL 25 June 2002, Moscow.

20. Rubtsov I.V., Pyatnitskaya T.A. (2013) Purpose and modern methods of instrumental geodetic monitoring of monuments of civil architecture. J Bulletin of MGSU, Moscow, Russia, 5: 80-86.
21. Sercan R. A. B., Ceren R. A. A. (2012) The applicability of the model three dimensional surveying for the protection of historical and cultural heritage: an example of province of Konya sille. International Multidisciplinary Scientific GeoConference: SGEM. June 2012. p 1169-1176.
22. Seryakova V.A., Fedulov A.A. (2016) Evaluation of objects of cultural heritage. https://cyberleninka.ru/article/n/otsenka-obektov-kulturnogo-naslediya. Accessed 10 Dec 2022.
23. Shashkin A. G., Shashkin V. A. (2021) Adjustment of requirements of regulatory documents about cultural heritage objects. Reconstruction and Restoration of Architectural Heritage 2021. CRC Press, July 2021 p. 290-296.
24. Shahinyan Sh.Z. (2019) Application of modern geodetic methods to preserve architectural monuments. Balandinsky readings 14(1):99-102.
25. Sheina S. G., Girya L. V., Burakova A. A., Gorskaya A. L. (2019) Methods of complex assessment of the state of architectural monuments. Construction and technogenic safety, 15(67): 7-13.
26. Solnyshkova O. V., Karavaev A. A. (2015) Problems of topographical and geodetic support of restoration of architectural heritage objects. Tavrian scientific reviewer. 3-2: 60-62. https://www.elibrary.ru/item.asp?id=24897693. Accessed 10 Dec 2022.
27. Tobiasz A. et al (2019). Review of methods for documentation, management, and sustainability of cultural heritage. Case study: Museum of King Jan III’s Palace at Wilanow. Sustainability, 11 (24): 2-42. doi:10.3390/su11247046.
28. Ulyanova N.B. (2020) Issues of preservation of the cultural heritage of russia and its influence on the design of modern art and culture Scientific research and development. Socio-humanitarian research and technology. 9(2): 3-6.
29. Varlamova L.D. (2014) Using geodetic methods to preserve cultural heritage objects. In: Modern problems of construction and life support: safety, quality, energy and resource saving. Collection of materials of the III All-Russian scientific-practical conference. North-Eastern Federal University named after M.K. Ammosov. Moscow, Russia p 462-468.
30. Zilberova I. Y., Novoselova I. V., Mohsen A. (2021) Organizational and technological approaches to the construction and technical expertise of cultural heritage sites. IOP Conference Series: Materials Science and Engineering. – IOP Publishing, february 2021. DOI: 10.1088/1757-899X/1083/1/012058.