

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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**EVALUATION OF THE IMPACT OF VERTICAL
MOVEMENTS OF THE EARTH'S CRUST
ON LEVELLING NETWORKS**

Summary of Doctoral Dissertation
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VERTINIMAS**

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Introduction

Topicality of the problem – together with the change of time geodetical benchmarks due to geodynamic processes make their altitude transformations, the accuracy of levelling networks is modified. The results of measurements received on performing levellings are applied for the solution of various tasks. That is why it is very important for the results of measurements to satisfy the accuracy requirements. Due to the fact that vertical movements of the Earth's crust under the influence of time tend to have a geodynamic impact on networks which fail to satisfy the requirements for accuracy, that is why repeated measurements are required in order to have highly qualified data. Therefore, it is important to determine the periodicity of repeated measurements.

Levelling network measurements have to be performed continuously and the results of measurements might be affected by systematic errors because of the vertical movements of the Earth's crust. Therefore, the impact has to be evaluated by calculating the corrections in terms of the results of measurements due to the effect of the recent vertical movements of the Earth's crust, then reduction of measurements has to be performed taking into account the selected moment of time.

Objective of the research – is the impact of the recent vertical movements of the Earth's crust on the results of levelling and levelling networks. The objective of the experiment deals with the levelling networks of the territory of Lithuania and results of their measurements.

Aim and tasks of the work is to investigate the impact of the recent vertical movements of the Earth's crust on the results of measurements obtained by levelling and on the levelling networks, to work out the methodology for their evaluation to be applied for compiling and maintaining levelling networks.

The main tasks of the work are:

1. To improve the methodology of evaluation of the vertical movements of the Earth's crust relationship with the geoindeces of the territory.
2. To carry out the research on improving the models of forecasting of the recent vertical movements of the Earth's crust by applying the groups of diverse geoindeces.
3. Theoretically to justify as well as work out the methodology of the evaluation of the impact of the recent vertical movements of the Earth's crust on the measurements of levelling and levelling networks and to perform experiments to prove their usage.

4. To work out the methodology to be able to carry out the reduction of the results of measurements in levelling taking into account the selected period of time as well as to investigate its implementation possibilities.

5. To determine the impact of the recent vertical movements of the Earth's crust on the levelling networks of Lithuania.

Methodology of research. Theoretical and experimental research performed by means of the principle of systematic analysis, mathematical statistical methods of evaluation of the vertical movements of the Earth's crust forecasting and their impact on the results of measurements.

Scientific novelty

1. The methodology applied for the evaluation of the impact of the recent vertical movements of the Earth's crust on the measured differences of altitudes and on the modifications of levelling networks accuracy in terms of time changes.
2. The methodology of forecasting of the vertical movements of the Earth's crust velocities taking into account the informative analysis of the geoindexes of the territory or their groups.
3. Reduction of measured differences of altitudes in terms of the selected moment of time by means of the improved models of vertical movements of the Earth's crust forecasting.

Practical value. By applying the prepared methodology of the reduction of measured differences of altitudes in terms of the selected moment of time, there were eliminated the systematic errors of measurements obtained during the process of executing levelling network measurements and which were caused by the impact of the vertical movements of the Earth's crust which resulted into the increase of accuracy of the levelling network.

By applying the revealed methodology on the evaluation of the impact of the vertical movements of the Earth's crust on the levelling networks, it is possible to make reasonable plans for the repeated measurements of levelling networks.

Defended propositions

1. Evaluation of the impact of the recent vertical movements of the Earth's crust in terms of time changes for compiling and maintaining the networks of levelling.

2. Application of the improved models of the vertical movements of the Earth's crust forecasting for compiling levelling networks; implementation of the results of the research made.
3. Influence of the results of the investigations regarding the impact of the recent vertical movements of the Earth' crust on the levelling network of Lithuania.
4. Recommendations to decrease the impact of the recent vertical movements of the Earth's crust to be applied in compiling and maintaining the levelling networks of Lithuania.

The scope of the scientific work. The scientific work consists of the general characteristic of the dissertation, four chapters, conclusions, list of literature, list of publications. The total scope of the dissertation is 166 pages, 68 figures, 40 tables, 63 numbered formulas. There were made use of 174 scientific literature sources available.

1. Review of the research on the recent vertical movements of the Earth's crust as well as their impact on geodetic networks

The article describes the geological structure of the Earth, its evolution and geological peculiarities of the territory of Lithuania. There are presented the possibilities of applying geodetic methods for the investigation of the recent vertical movements of the Earth's crust, the development of these methods within the sequence of time.

The analysis of scientific literature sources and publications was carried out concerning previous investigations made regarding the usage of geodetic methods for the recent vertical movements of the Earth's crust and regarding the evaluation of the Earth's crust movements and in terms of carrying out geodetic measurements and compiling a well as maintaining geodetic networks.

The problematic issues regarding the research were described, the necessity for further investigation and research into the matter was justified as well as the possibilities and the essential tasks to be solved in order the aim and tasks of the work to be fulfilled.

2. Upgrading of the methodology for the evaluation of the impact of the recent vertical movements of the Earth' crust on the network of levelling

Theoretical issues of upgrading required for the mentioned above tasks to be solved in terms of the impact of the recent vertical movements of the Earth's crust on the measurements of levelling, compiling and maintenance of levelling

networks and the models of the movements of the Earth's crust forecasting were analyzed.

To forecast the vertical movements of the Earth's crust regressive models are usually applied, which are derived by means of the repeated geodetic measurements and available data possessed on the geoindeces of the territory. Moreover, not all the geoindeces or their groups applied for forecasting have the same equal influence on the results and quality of forecasting. To have the informative and complexity evaluation of indexes or their groups, to be able eliminate greatly deviating indexes from the unanimous complex there is applied complex correlation analysis. To reduce the impact of random disturbances regarding the results of geodetic measurements and geologic indexes there are applied polynomic regressive equations.

To estimate the impact of the recent vertical movements of the Earth's crust on the measurements of levelling and levelling networks there are used horizontal gradient velocities of the vertical movements of the Earth's crust. Based on the theory of scalar fields, there is introduced the methodology for compiling maps of the horizontal gradient velocities of the vertical movements of the Earth's crust. The specific application peculiarities of these maps are analyzed to be able to use them for the evaluation of the impact of the movements of the Earth's crust on geodetic measurements.

Based on the conception and characteristics of horizontal gradient velocities of the vertical movements of the Earth's crust and the principals of the theory on mathematical statistics and error measurements, there was worked out the methodology to evaluate the impact of the vertical movements of the Earth's crust on the measurements of levelling and levelling networks.

Taking into consideration the prepared recommendations to evaluate the impact of the movements of the Earth's crust on the measurements of levelling and technological characteristics in compiling levelling networks, there was worked out the methodology concerning the reduction of the results of levelling measurements in terms of selected moment of time. The peculiarities were analyzed as well as prepared the recommendations for reduction of the measurements in terms of the selected moment of time contained in the lines of levelling networks possessing repeated geodetic measurements and in lines where such type of measurements were missing.

3. Upgrading of the models of forecasting in respect to recent vertical movements of the Earth's crust

The experimental research presented in this chapter was based on the methodology of upgrading the models of forecasting introduced in chapter 2.

To execute the detailed experiments there were chosen the measured velocities of the vertical movements of the Earth's crust during the periods of 1936–1963/64, 1936–1973/75, 1936–2003, 1954–1963/64, 1954–1973/75, 1954–2003, 1963/64–2003, 1973/75–2003 in the first class vertical geodetic network line of Lithuania i.e. Mikytai – Šilutė – Klaipėda and there were derived two groups of geo-indexes. The first group included the structural complexes of the ground sedimentary cover that were never before applied in forecasting (where x'_1 is the thickness of sedimentary cover, x'_2 is of Caledonian, x'_3 is of Hercinian, x'_5 are the thicknesses of Alpine complexes, x'_4 is the thickness of Lower Silurian, x'_6 is the strength of the magnetic field) while the second group included the geoindexes used by the other authors, where x_1 is the relief of the crystalline basement, x_2 is the thickness of the Pre-Quaternary cover, x_3 is the thickness of the sedimentary cover, x_4 is the magnetic field, x_5 is the thickness of the Quaternary cover, x_6 is the gravitation field, x_7 is the Earth's surface current relief. By applying the method of complex analysis the attempt was made to determine geoindexes with the measured vertical movements of the Earth's crust, connected by the closest statistical relationship, eliminating from the research the indexes bearing little information or disturbing the process of analysis. The informative evaluation of geoindexes is determined.

The analysis and experiments proved that the measured vertical movements of the Earth's crust are related more to the first group geoindexes than to the second group, namely with the thicknesses of Alpine complexes ($0.43 \leq |r_{ij}| \leq 0.90$), Hercinian complexes ($0.40 \leq |r_{ij}| \leq 0.89$), magnetic field ($0.31 \leq |r_{ij}| \leq 0.90$), the thickness of the sedimentary cover ($0.22 \leq |r_{ij}| \leq 0.74$), but the second group geoindexes are related more only with the magnetic field ($0.31 \leq |r_{ij}| \leq 0.90$), the relief of crystalline basement ($0.23 \leq |r_{ij}| \leq 0.79$), the thickness of sedimentary cover ($0.22 \leq |r_{ij}| \leq 0.74$), but the relationship is weak and of insignificant value with the rest.

The results of the complex correlation analysis allow deriving the conclusion that the greatest values of the estimates of complex correlation have the vertical movements of the Earth's crust and geoindexes x'_3, x'_5, x'_6 from the first group, geoindexes x_1, x_3 from the second group. The most informative members of the first group of geoindexes are x'_1, x'_3, x'_5, x'_6 , but in the second

group all the geoindexes there signify themselves by similar informative evaluation. This upgraded methodology allows to determine as well as to eliminate the geoindexes possessing the fair amount of informative evaluation which introduce unfavourable type of information into the process of analysis.

To investigate the dependence of the quality of the models of forecasting for the recent vertical movements on the groups of geoindexes, the regressive analysis of the velocities of these movements is carried out, by accepting the members of the first and the second groups of geoindexes as causative variables i.e. including all the members present in the groups as well as eliminating part of them, taking into consideration the results of the complex correlative analysis.

After deriving the regressive models and after carrying out their analysis it was assumed that by causative variables while applying the first group of geoindexes the coefficient of termination is within the boundaries of $0.78 \leq R^2 \leq 0.99$, five from nine regressive model are adequate to the results of measurings with the probability of $p \geq 0.99$, three correspond to $p \geq 0.95$, but the second group of geoindexes comprises $0.43 \leq R^2 \leq 0.86$, six from nine regressive models correspond to the results of the measurements with the probability of $p \geq 0.99$, two with the probability of $p \geq 0.95$, one with the lower probability than of $p \geq 0.95$. By causative variables considered, the first and second group members of the geoindexes, selected during the complex correlation analysis, are received the following results: the first group of geoindexes is $0.57 \leq R^2 \leq 0.83$, six from nine regressive models are adequate to the results of measurements with the probability of $p \geq 0.99$, three with $p \geq 0.95$. The second group of geoindexes is $0.06 \leq R^2 \leq 0.67$, six from nine regressive models are adequate to the results of measurements with the probability of $p \geq 0.99$, one with the probability of $p \geq 0.95$, but two with the lower probability than $p \geq 0.95$.

In Figure 1 there are correspondingly presented the measured and used to derive regressive models by applying both the groups of geoindexes as well as to forecast the velocities of the recent vertical movements of the Earth's crust for the periods of 1973/75–1936.

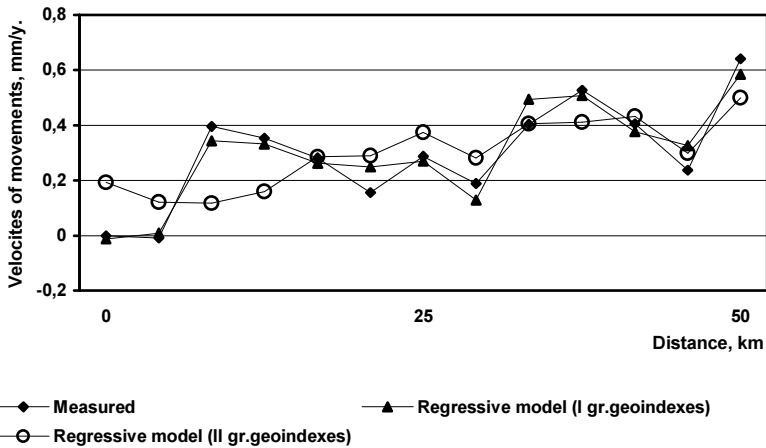


Fig. 1. Measured and forecasted velocities of the vertical movements of the Earth's crust for 1936–1973/75

It is possible to state, from the analysis made that the proposed upgraded methodology of the analysis presented in the second chapter of the work on the vertical movements of the Earth's crust, is efficient and if applied there could be received more qualitative models of forecasting.

By applying the method of analysis of complex correlation submitted in the second chapter there were made the investigations for the territory of Lithuania. There were analyzed the following geoindexes, namely x_1 is the Earth's surface current relief, x_2 is the thickness of the Pre-quaternary cover, x_3 is Pre-quaternary relief, x_4 is the thickness of the sedimentary cover, x_5 is the magnetic field, x_6 is the thickness of the Quaternary cover, x_7 is the relief of the crystalline basement, x_8 is the gravitation field. The investigations were executed for the separate lines of the vertical geodetic networks of Lithuania. The geological structure of Lithuania in different locations is not the same and in accordance with the position of levelling line, there were received diverse groups of the most informative indexes. That is why the models of forecasting the movements are required to be derived for individual regions taking into account the peculiarities of the territory.

4. The research of the impact of the recent vertical movements of the Earth's crust on compiling the network of levelling for Lithuania

The research is made according to the sample of the first class vertical geodetic network of Lithuania.

By applying the suggested methodology presented in the second chapter of this work there was compiled the map of horizontal gradients on the velocities of the vertical movements of the Earth's crust for the territory of Lithuania (Fig. 2).

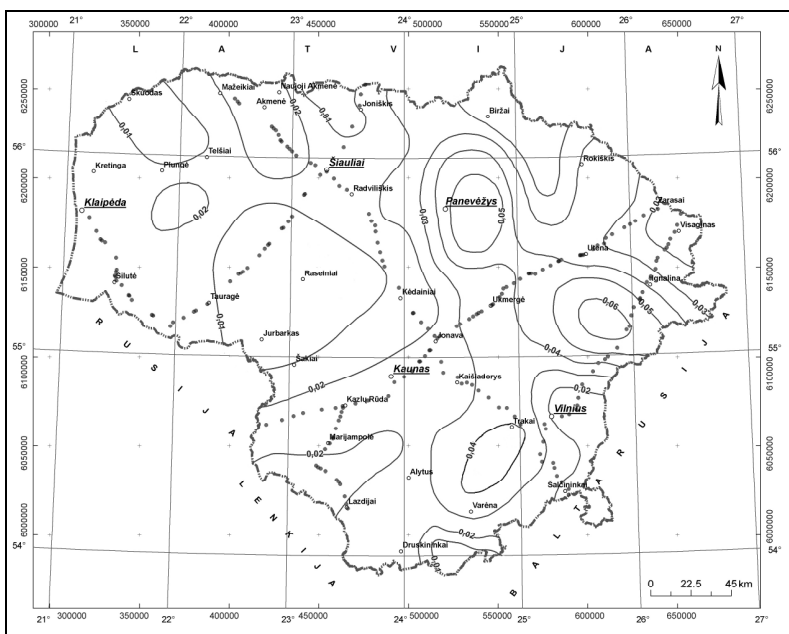


Fig. 2. Map of modulus of horizontal gradients on the vertical movements of the Earth's crust (values of gradients are in (mm/y.) / km)

The map assisted the investigation of the impact of the vertical movements of the Earth's crust on the accuracy of levelling network of Lithuania within the change of time. It was determined that within ten years since the time it was compiled the requirement for accuracy regarding the first class levelling is not satisfied by 70% and the second class is not satisfied by about 55% from the total number of networks located in the territory of Lithuania. In 20 years the

requirements for the first class levelling accuracy will not be satisfied for the whole network, but the requirement for the second class levelling accuracy will not be satisfied by about 70% of the levelling networks. That is why it is possible to state that in order to preserve the required accuracy of the first and second class levelling networks, it is necessary to carry out repeated measurements and upgrading of the networks within less than every 15–20 years.

By applying the methodology and recommendations presented in chapter two and three of this work in order to upgrade the forecasting models for the vertical movement of the Earth's crust there were carried out the experiments on the reduction of the results of measurements of levelling in terms of the selected moment of time, by applying various models of forecasting. When executing the testing of the levelling line Mikytai – Šilutė – Klaipėda in 1973/75 the reduction was used for the results of measurements for 2003. The results are presented in Fig. 3.

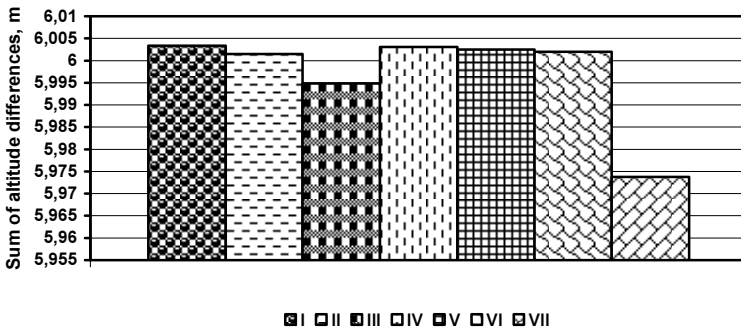


Fig. 3. Reduced differences of altitudes by applying forecasting models compiled according to the following: I – smoothed measured values of the velocities of the vertical movements of the Earth's crust, II is the first group of geoindeces selected by the complex correlation analysis method, III is the second group of geoindeces selected by the complex correlation analysis method, IV are all the geoindeces of the first group, V are all the second group indexes. The differences of altitudes were measured: VI measured in 2003, VII measured in 1973/75

From the detailed tests in the levelling line of Mikytai – Šilutė – Klaipėda there was determined that if applying the proposed methodology of selecting the groups of geoindeces for forecasting and the proposed new geoindeces (the

thicknesses of structural complexes of the ground sedimentary cover), then the quality of forecasting models is improved by about 10–15%, if compared with the previously applied regressive models of forecasting regarding the vertical movements of the Earth's crust.

By applying the proposed method presented in chapter two of the work regarding the correction in terms of the reduction of the results of the measurements with the selected moment of time, there were made the repeated calculations in the levelling lines, in the levelling polygon of Jonava – Zarasai – Turmantas. The measurements were made in 1998–2006. The tests determined that when the reduction of the results of the measurements were made for 2000, the correction for the geodetic benchmark, was up to 25 mm, when for 2005 it is up to 5 mm but reducing the measurement of levelling into 2005 years the corrections due to the collection of the sums of the vertical movements of the Earth' crust in the polygon are about twice higher than the sums of the collection of normalized corrections. Disconnection in polygon, after the computation of the normal, without the reduction in terms of a single moment of time, altitudes, is equal to +4.39 mm, but after the computation the reduced ones for 2005, it is equal to +2.19 mm.

By applying the methodology for corrections to compute the reduced results of the measurements into the selected moment of time when in the lines of levelling there are missing the repeated measurements, there were made tests in the levelling polygon of Jonava – Zarasai – Joniškis – Šiauliai – Jonava, The measurements there were made in 2004–2006. In the levelling line Zarasai – Joniškis the repeated measurements were missing. By tests there were determined that when reducing the measurements into 2000, the corrections for the geodetic benchmark is up to 25 mm, and reduced into 2005 is up to 5 mm. While reducing the measurements of levelling into 2005, the corrections due to the collection of the sum of the vertical movements of the Earth's crust in the polygon are about twice higher than the collection of normal corrections, but disconnection is in the polygon when the measured differences of altitudes are 33.25 mm, when reduced into 2005 they are 29.06 mm.

General conclusions

Based on the doctoral dissertation research there were derived the following generalized conclusion:

1. Theoretical research enabled to work out the methodology targeted to estimate the impact of the recent vertical movements of the Earth's crust on the measurements of levelling and alternations of the accuracy of levelling network within the sequence of time. The methodology proposed makes it possible to

plan repeated geodetic measurements of levelling networks for the required accuracy to be preserved in terms of the altitude basin.

2. The methodology was presented allowing reducing measured differences of altitudes taking into account vertical movements of the Earth's crust and the selected moment of time. By reducing the measurements the influence of systematic errors is decreased due to the impact of vertical movements of the Earth's crust on to the errors of levelling.

3. Regressive models which are derived by means of the general mathematical statistical analysis of repeated geodetic measurements and territorial geoindeces are recommended to be applied in forecasting the velocities of movements required for the evaluation of the impact of vertical movements of the Earth's crust on the measured differences of altitudes and for performing reduction of measurements notifying the selected moment of time.

4. Here is recommended to determine the informative evaluation regarding the groups of geoindeces when compiling the models of forecasting for the vertical movements of the Earth's crust by means of the methodology of complex correlation analysis and reverse stepping regression. That enables to improve the quality of forecasting models by about 15% in average.

5. To assess the impact of the vertical movement of the Earth's crust for the levelling networks of Lithuania there was compiled the map of horizontal gradient velocities of the vertical movements of the Earth's crust. The conclusion derived implies that in 10 years about 70% of the first class levelling networks would not satisfy the accuracy requirements for maintenance, and in 20 years all the total network would fail the requirements for accuracy. Accuracy requirements for the second class network in 10 year would not be satisfied by about 55% and in 20 years it would reach 70%.

6. The sums of reduction corrections of altitude differences in separate observations, in terms of the Lithuanian first class levelling network when specifying the selecting moment of time, up to four times exceed the sums of normalized corrections (line Jonava–Turmantas).

7. The altitude errors of geodetic benchmarks appearing as the result of not considering the impact of the vertical movements of the Earth's crust during the process of compiling the first class levelling networks of Lithuania turn to be three times higher than the errors of measurements.

8. In order to preserve the required accuracy prescribed while maintaining the first and second class levelling network of Lithuania it is necessary to carry out repeated measurements of levelling networks every 15–20 years. While the processing of results of measurements the measured differences of altitudes have to be reduced taking into account the selected moment of time.

List of Published Works on the Topic of the Dissertation

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VERTIKALIŲJŲ ŽEMĖS PLUTOS JUDESIŲ ĮTAKOS NIVELIACIJOS TINKLAMS VERTINIMAS

Mokslu problemos aktualumas. Einant laikui geodeziniai ženklai dėl vykstančių geodinaminių procesų keičia savo aukščius, mažėja niveliacijos tinklų tikslumas. Niveliacijos matavimų rezultatai naudojami įvairiems uždaviniams spręsti, todėl labai svarbu, kad matavimų rezultatai atitiktų keliamus tikslumo reikalavimus. Kadangi, einant laikui, dėl vertikalųjų žemės plutos judesių poveikio įtakos tinklai pradeda nebeatitikti tikslumo reikalavimų, siekiant turėti kokybiškus duomenis reikia, atlikti kartotinius matavimus. Todėl svarbu nustatyti kartotinių matavimų periodiškumą.

Atliekami niveliacijos tinklo matavimai trunka tam tikrą laikotarpį. Todėl matavimų rezultatams įtaką darys sistemingosios paklaidos, atsiradusios dėl vertikalųjų žemės plutos judesių poveikio. Svarbu įvertinti šį poveikį, apskaičiuojant pataisas dėl dabartinių vertikalųjų žemės plutos judesių poveikio į niveliacijų matavimo rezultatus, matavimų rezultatus redukuoti, atsižvelgiant į pasirinktą laiko momentą.

Tyrimų objektas – dabartinių žemės plutos judesių įtaka niveliacijos matavimų rezultatams ir niveliacijos tinklams. Eksperimento objektas – Lietuvos teritorijos niveliacijos tinklai ir jų matavimų duomenys.

Darbo tikslas ir uždaviniai. Ištirti dabartinių vertikaliųjų žemės plutos judesių įtaką niveliacijos matavimų rezultatams ir niveliacijos tinklams, parengti jų vertinimo metodiką, sudarant ir eksploatuojant niveliacijos tinklus.

Darbo tikslui pasiekti darbe reikia spręsti šiuos uždavinius:

1. Patobulinti vertikaliųjų žemės plutos judesių sąsają su teritorijos georodikliais vertinimo metodiką.
2. Atlikti dabartinių vertikaliųjų žemės plutos judesių prognozės modelių tobulinimo tyrimus, taikant skirtingų georodiklių grupes.
3. Teoriškai pagrįsti ir parengti dabartinių vertikaliųjų žemės plutos judesių įtakos niveliacijos matavimams ir niveliacijos tinklams vertinimo metodiką bei atlikti jos taikymo tyrimus.
4. Parengti metodiką niveliacijos matavimų rezultatams redukuoti, atsižvelgiant į pasirinktą laiką ir atlikti jos taikymo tyrimus.
5. Ištirti dabartinių vertikaliųjų žemės plutos judesių įtaką Lietuvos niveliacijos tinklams.

Tyrimų metodika apima teorinius ir eksperimentinius tyrimus, taikant sisteminės analizės principus, matematinius statistinius vertikaliųjų žemės plutos judesių prognozavimo ir jų įtakos matavimo rezultatams vertinimo metodus.

Mokslinis naujumas

Disertaciniame darbe gauti nauji rezultatai:

1. Dabartinių vertikaliųjų žemės plutos judesių įtaka išmatuotiems aukščių skirtumams ir niveliacijos tinklų tikslumo kaitai, einant laikui, vertinimo metodika.
2. Patobulinta vertikaliųjų žemės plutos judesių greičių prognozavimo metodika, atsižvelgiant į teritorijos georodiklių ir jų grupių informatyvumą.
3. Išmatuotų aukščių skirtumų redukavimas, atsižvelgiant į pasirinktą laiką, taikant patobulintus vertikaliųjų žemės plutos judesių prognozės modelius.

Praktinė vertė. Taikant parengtą išmatuotų aukščių skirtumų redukavimo, atsižvelgiant į pasirinktą laiko momentą metodiką, eliminuojamos dėl vertikaliųjų žemės plutos judesių poveikio niveliacijos tinklo matavimų laikotarpiu atsirandančios sistemingosios matavimų paklaidos. Dėl to padidėja niveliacijos tinklo tikslumas.

Taikant parengtą vertikaliųjų žemės plutos judesių įtakos niveliacijos tinklams vertinimo metodiką, galima pagrįstai planuoti niveliacijos tinklų kartinuos matavimus.

Ginamieji teiginiai

1. Dabartinių vertikaliųjų žemės plutos judesių įtakos, einant laikui, vertinimas, sudarant ir eksploatuojant niveliacijos tinklus.
2. Patobulintų vertikaliųjų žemės plutos judesių prognozės modelių taikymas, sudarant niveliacijos tinklus; tyrimo rezultatai.
3. Dabartinių vertikaliųjų žemės plutos judesių poveikio Lietuvos niveliacijos tinklui tyrimo rezultatai.
4. Rekomendacijos vertikaliųjų žemės plutos judesių poveikiui sumažinti eksploatuojant ir sudarant Lietuvos niveliacijos tinklus.

Darbo apimtis. Darbą sudaro bendra darbo charakteristika, keturi skyriai, išvados, literatūros sąrašas, publikacijų sąrašas. Bendra disertacijos apimtis – 166 puslapiai, 68 iliustracijos, 40 lentelės ir 63 numeruotos formulės.

Pirmame disertacijos skyriuje atlikta dabartinio teritorijos tektoninio aktyvumo, jo įtakos geodeziniais tinklams tyrimų apžvalga, išaiškinti probleminiai tyrimų klausimai, pagrįstas tolesnių tyrimų būtinumas ir galimybės bei pagrindiniai spęstiniai uždaviniai darbo tikslui pasiekti.

Antrame disertacijos skyriuje analizuojama ir pateikiama dabartinių vertikaliųjų žemės plutos judesių įtakos niveliacijos tinklams bei jų matavimams vertinimo metodikos tobulinimas.

Trečiajame skyriuje pateikiamas dabartinių vertikaliųjų žemės plutos judesių prognozės modelių tobulinimas, rezultatai.

Ketvirtajame skyriuje pateikiamas dabartinių vertikaliųjų žemės plutos judesių įtakos, sudarant niveliacijos tinklus, tyrimas ir jo rezultatai.

Bendrosios išvados

Remiantis disertaciniame darbe atliktais tyrimais, gautos šios apibendrintos išvados:

1. Remiantis teoriniais tyrimais, parengta metodika įvertinti dabartinių vertikaliųjų žemės plutos judesių įtaką niveliacijų matavimams ir niveliacijos tinklo tikslumo kaitą, einant laikui. Taikant šią metodiką, galima planuoti kartotinius niveliacijos tinklų geodezinius matavimus, kad būtų išlaikytas reikiamas aukščių pagrindo tikslumas.

2. Parengta metodika išmatuotiems aukščių skirtumams redukuoti, įvertinant vertikaliuosius žemės plutos judesius ir atsižvelgiant į pasirinktą laiko momentą. Redukuojant matavimus, sumažinama dėl vertikaliųjų žemės plutos judesių poveikio atsirandančių sistemingųjų paklaidų įtaka niveliacijos tinklo paklaidoms.

3. Vertinant vertikaliųjų žemės plutos judesių įtaką išmatuotiems aukščių skirtumams bei atliekant matavimų redukavimą, atsižvelgiant į pasirinktą laiką, judesių greičiams prognozuoti rekomenduojama taikyti regresinius modelius,

sudarytus remiantis bendra kartotinių geodezinių matavimų ir teritorijos georodiklių matematine statistine analize.

4. Sudarant vertikaliųjų žemės plutos judesių prognozės modelius, rekomenduojama nustatyti georodiklių grupių informatyvumą, taikant kompleksinės koreliacinės analizės metodiką bei atvirkštinę žingsninę regresiją. Tai leidžia vidutiniškai apie 15 % pagerinti prognozės modelių kokybę.

5. Vertikaliųjų žemės plutos judesių įtakai Lietuvos niveliacijos tinklams vertinti sudarytas vertikaliųjų žemės plutos judesių greičių horizontaliųjų gradientų žemėlapis. Nustatyta, kad po 10 metų eksploataavimo tikslumo rezultatų neatitiks apie 70 proc. pirmosios klasės niveliacijos tinklo, o po 20 metų – visas tinklas neatitiks jam keliamų tikslumo reikalavimų. Antrosios klasės tinklo tikslumo reikalavimų neatitiks po 10 metų – apie 55 ir po 20 metų – apie 70 proc.

6. Lietuvos pirmosios klasės niveliacijos tinkle aukščių skirtumų redukavimo, atsižvelgiant į pasirinktą laiko momentą, pataisų sankaupos atskiruose niveliacijos ėjimuose iki keturių kartų viršija normalinių pataisų sankaupas (linija Jonava–Turmantas).

7. Dėl vertikaliųjų žemės plutos judesių poveikio neįvertinimo, sudarant Lietuvos pirmosios klasės niveliacijos tinklą, atsirandančios geodezinių ženklų aukščių paklaidos apie tris kartus didesnės už matavimų paklaidas.

8. Eksploataavimo laikotarpiu norint išlaikyti reikiamą pirmosios ir antrosios klasės Lietuvos niveliacijos tinklų tikslumą, niveliacijos tinklų kartotinius matavimus reikia atlikti kas 15–20 metų. Apdorojant matavimų rezultatus, išmatuoti aukščių skirtumai turi būti redukuoti, atsižvelgiant į pasirinktą laiko momentą.

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**EVALUATION OF THE IMPACT OF VERTICAL MOVEMENTS OF
THE EARTH'S CRUST ON LEVELLING NETWORKS**

Summary of Doctoral Dissertation

Technological Sciences, Measurement Engineering (10T)

Rūta Puzienė

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NIVELIACIJOS TINKLAMS VERTINIMAS**

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