VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Lina JUKNEVIČIŪTĖ-ŽILINSKIENĖ

METHODOLOGY FOR THE EVALUATION OF THE EFFECT OF THE CLIMATE OF LITHUANIA ON ROAD CONSTRUCTION AND CLIMATIC REGIONING

Summary of Doctoral Dissertation

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

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LIETUVOS KLIMATO ĮTAKOS KELIŲ TIESYBAI VERTINIMO METODIKA IR KLIMATINIS RAJONAVIMAS

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Introduction

Topicality of the problem. Lithuania is one of those countries which experience a large influence of climatic conditions on road design, construction, repair and maintenance. Besides vehicle-generated loads, motor roads are continuously affected by a large number of climatic factors. Weather conditions, such as sudden wind, snow, snowstorm with glazed frost, summer and winter differences in the air temperature do not only change condition of the road pavements but also make a negative effect on vehicle performance and the driver's behaviour. In our country 3–4 months per year the air temperature keeps below 0°C, at longest in the Eastern Lithuania, at shortest – on the coast. Already in the second half of November on the average the first snow cover is formed, lasting until the mid March. In winter Lithuania faces frequent thaws, the daily temperature varies around zero, there is a large probability of freezing rain, glazed frost and fog. Despite a large whether variation the certain regularities are still observed characteristic to a particular region. The most general features of the climate of Lithuania are determined by geographical latitude, solar radiation, atmospheric circulation and interaction of these factors with the terrene. From local factors, forming the climate of Lithuania, the most important is the distribution of continents, the ocean and the seas.

According to the regularities of hydro-thermal regime the whole territory of the Eastern Europe is divided into five road climate zones. Lithuania belongs to the 2nd climatic road zone. However, when designing, constructing or maintaining roads one should take into consideration not only the average climatic indices for the whole Lithuania but also to thoroughly analyze data provided by the meteorological stations, located in the closest proximity to the road, and the road weather information systems. Based on the most characteristic weather conditions the territory of Lithuania is divided into regions and sub-regions, however, this climatic regioning is more geographical. The regions are not interrelated by one or another climatic index, therefore, the efforts to divide the territory of Lithuania by the climatic factors is a necessity from the point of view of road specialists.

Climatic forecast, or in other words – forecast of weather conditions, is very important information for road organizations, road maintenance enterprises and road users.

For road construction the most important climatic indices are: air temperature and a number of its transitions over 0 °C, depth of frozen ground, amount and intensity of precipitation, a number and duration of storms, data about freezing rain.

This scientific work is directly related to the climatic indices recorded by the Lithuanian Hydrometeorological Service (LHS) and the Road Weather Information System (RWIS).

Taking into consideration all the climate peculiarities the problem of the work is to identify:

- if the climatic differences in the territory of Lithuania make any effect on the road construction, repair and maintenance works;
- if the currently validated one climate zone is enough for Lithuania.

When these questions are answered, to determine the distribution of climatic factors within the territory of Lithuania and to suggest its regioning from the point of view of road design, construction and maintenance.

Research object – climatic factors having the effect on road construction. Experimental object – parameters recorded by RWIS (1999–2008) and LHS (1961–1990).

Aim and tasks of the work – to make a climatic regioning of the territory of the Republic of Lithuania from the point of view of road construction.

The following tasks must be solved to achieve the aim of this work:

1) To analyze and evaluate the foreign practice in territorial regioning from the point of view of road construction.

2) To carry out analysis and comparison of data parameters recorded by the Lithuanian Hydrometeorological Service and the Road Weather Information System.

3) To determine maximum and minimum depth of frozen ground and the temperature of air and road pavement surface.

4) To form the regions (maps) of the depth of frozen ground taking into consideration the influencing factors.

5) To make maps of wind speed and direction.

6) To make the maps of freezing and thawing cycles (transitions over 0 °C) taking into consideration the influencing factors.

7) To determine the effect of different factors (snowstorms, thickness of snow cover, freezing rain) on road maintenance organization in a cold period of the year by deriving climatic coefficients.

8) Taking into consideration climatic factors when designing, constructing and maintaining roads to suggest possibilities for the implementation of the regioning of Lithuania from the point of view of road construction.

Methodology of research. Seeking to achieve the aim of the work the research methods such as statistical analysis, comparison, grouping, elaboration, generalization and graphical representation of data were used.

The analysis of climatic regioning methodologies, used in Lithuania and other foreign countries, was carried out. When analyzing data of climatic factors, received from LHS and RWIS, the statistical and comparative analysis methods were used. The multi-year (1961–1990) LHS and 1999–2008 RWIS data on frozen ground, precipitation, wind, etc. have been analyzed.

For processing a huge amount of data the Database Management System MS Access was chosen. Data from meteorological stations was supplemented with station coordinates re-calculated from the ellipsoidal to plain. Such information allows to mark the stations in the geographical information systems and to create the subject maps of Lithuania with AutoCad Civil 3D.

Scientific novelty. For the first time Lithuania has been regioned from the point of view of road construction, taking into consideration the most important factors: depth of frozen ground, air temperature, freezing and thawing cycles, wind speed and direction.

In respect of climatic regioning separate territories can be characterized if the historical climatic indices of no less than 7 years are available. Having data of the LHS multi-year observations, and the RWIS data is recorded since 1999, it's up to the purpose to make a climatic regioning of roads based on different climatic factors, and the reliable results could be obtained.

Within the framework of this scientific work the analysis of climatic factors was carried out which showed that every region should be attributed a climatic coefficient, on a basis of which the quantities of works would be identified and the funds allocated to a winter maintenance enterprise would be calculated. Climatic coefficient would depend on the thickness of snow cover, number of days with freezing rain and snowstorms and duration of snowstorms.

Practical value. The theme of this dissertation is topical to the road and utility specialists of Lithuania in a practical aspect. The analysis made and the results obtained will help to more easily solve the issues of road design, construction, repair and maintenance in Lithuania, taking into consideration the effect of climatic factors.

Defended propositions

1. Heterogeneousness of the climate of the territory of Lithuania is assessed from the point of view of road construction.
2. Climatic factors have a large effect on road design, construction and reconstruction.
3. The currently available RWIS data supplements and specifies the data of LHS, besides, on the basis of RWIS data a more accurate (of the depth of frozen ground, freezing/thawing cycles of road pavement, wind speed and direction, air temperature) regioning is made, facilitating the activities of road design, repair, construction and maintenance enterprises.
4. Climatic regioning of Lithuania according to climatic parameters having the effect on road construction processes.

5. It is suggested to introduce a climatic coefficient which will help to determine the quantities of maintenance works and to correct winter maintenance costs.

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 and addenda. The total scope of the dissertation – 127 pages, 74 pictures, 5 tables and 4 addenda.

1. Review of Research of the Climate of Lithuania

Already in the second half of XVII century when Galileo Galilei and his followers invented thermometer, barometer and rain gauge it became possible to carry out instrumental observations.

In about 1820, thanks to G. V. Brandes (Germany), the first synoptic maps appeared, and in 1849, in Russia (Saint Petersburg) the first in the world scientific centre of climatology was established. Later in the other countries the national meteorological centres were also created which cared about the establishment of new meteorological stations, methodology for the observations and data processing. In 1845 Berhaus worked out the first world map of precipitation, in 1859 W. Ferrel (USA) created fundamentals for the general atmospheric circulation theory, and the first wind rose was formed in 1870 by the Frenchman L. Brault. At the end of XIX century, with the establishment of meteorological stations and accumulation of information about climate, the first works appeared presenting climate classifications. In 1884 A. Vojeikov and W. Köppen suggested to divide the Earth into temperature lanes based on natural factors – this was a large step forward of climatology.

In the 20th century the climate atlases and handbooks of the world and various countries were worked out, new climate classifications were created, methodology for the processing of meteorological data was improved. In 1930–1936 W. Köppen and R. Geiger produced a five-volume work "Handbuch der Klimatologie" (Handbook of Climatology). From 1900 to 1936 W. Köppen was modifying his climate classification. His classification system includes 5 climatic lanes and 12 climate types. Later this classification was further modified and supplemented by R. Geiger. Until now the climate classification system by W. Köppen and R. Geiger is treated as one of the most perfect. It has been improved and supplemented up to now. Based on Köppen and Geiger climate classification system the world map was renewed in 2006 by the scientists M. Kottek, J. Grieser, C. Beck, B. Rudolf and F. Rubel.

Data from the first meteorological stations of Lithuania was used merely for describing the climate of the territory. In the 20th century it became more important to practically and rapidly use meteorological information related to the increased demand for meteorological measurements. The first regular instrumental meteorological measurements were started in Lithuania in 1771, in the Astronomical Observatory of Vilnius University. With the initiative of Professor M. Počobutas the regular measurements of air temperature were started in Vilnius (data is available since 1777), somewhat later – measurements of wind direction, precipitation (since 1887) and other weather indicators. In 1892 a network of meteorological measurements was originated. In 1923 the National Hydrometeorological Service was established.

After the World War II investigations of the climate of Lithuania were carried out by the famous scientists B. Styra, K. Kaušyla, B. Kavaliauskas, Č. Garbaliauskas, V. Ščemeliovas, and others. Climate classifications by B. Alisovas and M. Budykas are used up to now. According to B. Alisovas genetic climate classification K. Kaušyla made the scheme of the climatic regioning of Lithuania. Data accumulated in about 200 years was generalized by many scientists. A great many of scientific works and books have been written describing the influencing factors of the climate of Lithuania, studying specific territorial features of different meteorological elements and climate variations. Manuals of the main meteorological elements and phenomena have been published and are still published. A fair amount of investigations of applied nature were carried out by professor A. Bukantis (publication "The Climate of Lithuania", 1994), meteorologists E. Rimkus and J. Kažys. The developing economy generated intensive development of a number of trends of applied climatology: aviation, medicine, construction, road and transport, etc.

In 1995 the National Construction Regulations RSN 156-94 "Construction climatology" were published which present climate data used designing buildings, structures, heating, aeration and conditioning systems, water-supply, electricity lines, etc.

In Lithuania the effect of climatic factors on roads was studied by A. I. Tamaševičius. It is emphasized in his work that under the changeable climate of Lithuania (from maritime to continental), having many regional peculiarities, the Republic of Lithuania cannot be attributed to the climate zone II according to the general climatic regioning of roads. The Baltic States must be distinguished by a separate sub-zone. S. Lukošiūnas, with the help of engineering theoretical and analytical methods for forecasting the depth of frozen ground, has developed methodology for the determination of the depth of frozen ground and pavement structures and for the calculation of climatic coefficient.

Climatic coefficient α_0 depends on the depth of frozen subgrade z and the freezing duration T_{sk} (number of cold days with the temperature below 0 °C). The coefficient is defined by the formula:

$$\alpha_0 = \frac{z^2}{2T_{sk}}, \tag{1}$$

where T_{sk} – estimated number of cold days defined from the isoline map and by the formula $T_{sk} = \beta_1 T_v$, where β_1 – coefficient showing a probability of recurrence of the number of cold days in a certain period. For the probabilities $P(T_{sk})$ = 0.05; 0.10 and 0.20 the corresponding values of β = 1.18; 1.25 and 1.35 are taken; z – the depth of frozen ground in a particular location which is found by the formula (2):

$$z = \sqrt{\frac{48\lambda_g J_{sk}}{q_g}}, \tag{2}$$

where λ_g – coefficient of heat conductivity of the frozen ground, kkal/m^{3}h deg, is defined by the standards; J_{sk}, J_v – estimated and average number of degrees below freezing – days, defined from the isoline maps and by the formula $J_{sk} = \beta J_v$, where β – coefficient showing a probability of recurrence of the number of degrees – days in a certain period. For the probabilities P(J_{sk}) = 0.05; 0.10 and 0.20 the corresponding values of β = 1.40; 1.70 and 1.94.

2. Theoretical Substantiation for the Climatic Regioning of Lithuania

There are many different world-wide principles of climatic regioning. Climatic regions are determined not only by separate meteorological elements but also by their complexes. The general theoretical climatographical schemes are being developed, climatic regioning of applied nature is being made.

The neighbouring countries when designing, constructing, repairing and maintaining roads, for example Belarus, first of all take into consideration the annual precipitation sum and monthly distribution of precipitation, the annual regime of air temperature, regime of snow cover formation, speed and strength of wind, regime of the depth of frozen ground. The most important climatic factors for the Great Britain are air temperature, precipitation and wind. Sweden pays a particular attention to the information about the climatic conditions of roads in winter (precipitation >0 mm, air temperature >0 °C, road surface temperature ≤0 °C).

Most of the road specialists in the other countries use the maps developed by meteorological services based on multi-year data.

The largest attention of the road specialists is paid to a winter season when weather conditions are especially bad. For this purpose the territory of Canada is additionally regioned into 6 regions according to the average maximum snow depth from data of 18 winters (1979–1997). Japan divides its territory into four winter regions. In winter the German territory is regioned into three zones according to the frost index.

On the roads of many countries the RWIS stations have been installed which record and supply necessary data, however, the most frequently analyzed values of climatic factors are those obtained in winter. The territory of Lithuania is attributed to the road climate zone II, though, when designing, constructing or maintaining roads the currently validated one climate zone is not enough. It would be necessary to make a detail analysis of data provided by the nearest to that road meteorological stations and RWIS.

Based on B. Alisov‘s climate classification the territory of Lithuania is divided into four regions and ten sub-regions, but this climatic regioning is more of geographical nature. The territory of Lithuania is regioned also by the multi-year LHS data, though the road specialists need more accurate information related to roads. Therefore, the effort to divide the territory of Lithuania by the climatic factors is a necessity from the road construction point of view.

When designing frost-blanket courses and waterproofing layers, it is necessary to know the depth of frozen ground, subgrade and hydro-thermal regimes, influence of air temperature and solar radiation on the heating of pavement surface. Road pavements are mostly affected by a negative temperature, the impact of which (Fig. 1) can be expressed in the thickness of frost-blanket course. Thickness of this course depends on the frost-susceptibility of soil.

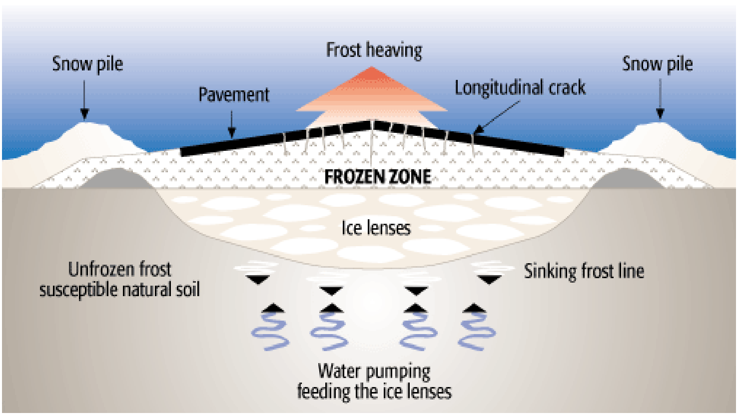

Fig. 1. The scheme of the impact of frozen ground on road structure

To describe intensity of frost the Frost Index *FI* can be used. The Frost Index is expressed in the average sum of days with a negative temperature.

$$FI = \sum_{i=1}^{n} (0 - T_i), \tag{3}$$

where *FI* – Frost Index, ºC; T_i – mean air temperature of *i*-day, ºC; *n* – the days of a definite period with a negative mean air temperature; *i* – number of days with a negative temperature.

The Frost Index like the Thawing Index *TI* can be calculated using the RWIS data (air and road surface temperature):

$$TI = -T_{ref}, \tag{4}$$

where *TI* – Thawing Index expressed in days with a certain temperature, ºC; T_{ref} – calculated temperature, ºC.

$$T_{ref} = \overline{T_{Air}} - \overline{T_{Sfc}} \cdot \frac{\sum (T_{Sfc_i} - \overline{T_{Sfc}}) \cdot (T_{Air_i} - \overline{T_{Air}})}{\sum (T_{Sfc_i} - \overline{T_{Sfc}})^2}, \tag{5}$$

where T_{Air_i} –air temperature value in a particular location in *i*-day; T_{Sfc_i} – surface temperature value in a particular location in *i*-day.

The Thawing Index describes the influence of increasing air temperature on the road surface. It is used to find out the duration of spring thaw on roads.

Construction of motor roads from technological as well as organisational point of view is largely dependent on weather conditions. During rainy days it is necessary to observe how a water discharge system is functioning, what is the condition of shoulders and subgrade. If it snows the roads must be cleaned, during freezing rains – the roads must be spread. Under dry and hot weather the dustiness of gravel roads must be reduced. When solar radiation is large the strength of asphalt pavement decreases and this can result in the wash-out of bitumen.

3. Research in the Substantiation of the Territorial Regioning and Evaluation of Results

Initial meteorological information consists of data of multi-year observations carried out in the stations of Hydrometeorological Service. Other meteorological information, especially important to road construction, is received from the Road Weather Information System.

The RWIS, established in 1998, supplements and specifies the network of LHS stations existing for already many years. Parameters, recorded by RWIS, have a great practical value for the design, construction and maintenance of road structures. The most important parameters are: temperature of pavement structure at a different depth, pavement surface temperature, wind direction and speed, type and amount of precipitation. Besides the directly recorded climatic parameters it is very important to know the derived characteristics of multi-year values of these parameters – annual number of cycles of pavement surface temperature transitions over 0 °C, maximum depth of frozen ground, mean air temperature of the cold and warm seasons, "roses" of wind speed and intensity in the different regions of the country, etc. This data is representative since it covers a 10-year period.

The RWIS supplements and specifies the network of Hydrometeorological stations existing for already many years. The RWIS data facilitates the activities of road maintenance enterprises – gives information on road condition, helps to more easy and cost-effectively design, construct, repair and maintain roads, to manage unfavourable situations to the road users caused by road accidents and natural calamities, ensures a more safe traffic on the roads of national significance, especially in a cold period of the year.

Having processed data of meteorological stations it is possible to compile the subject maps of Lithuania. Those maps give a possibility to represent the distribution of values of one or another parameter within the territory of Lithuania measured in the stations. It is possible to compile a map of the depth of frozen ground, air temperature, the freezing/thawing cycles of pavement surface, wind speed and direction, precipitation, etc.

Subject maps, made according to RWIS data, can be used by all users but for the road enterprises which execute road construction works they are especially topical: data from the maps of the depth of frozen ground and freezing cycles of pavement surface are recommended to be used for predicting pavement defects; the maps of wind speed and direction – for forecasting road sections to be covered with snow; air temperature maps – for organizing construction works; the maps of freezing rain or snowstorm duration, as well as the maps of snow cover thickness should be used to derive climatic coefficients for each region (zone).

A possibility of creating subject maps is demonstrated by the map of the average wind speed with wind roses (Fig. 2) compiled according to the data of 1999–2008 cold seasons.

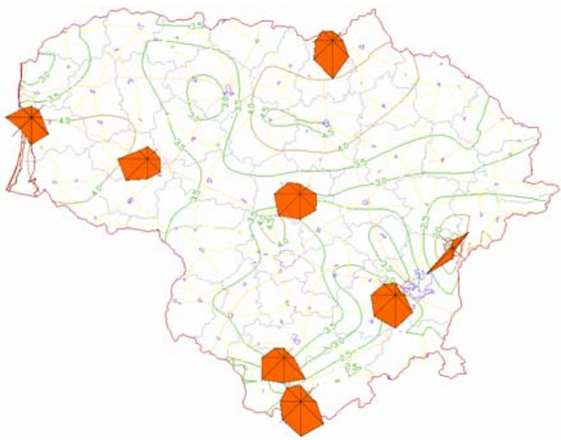

Fig. 2. The map of the average wind speed with wind roses compiled according to the data of 1999–2008 cold seasons

Subject maps give a rather accurate view on the variation regularities of the selected factors within a territory. Using a method of interpolation between the isolines it is possible in those maps to determine the values of those locations where no observations were carried out.

Statistical processing and analysis of LHS and RWIS data showed certain climatic differences. They are caused by the different existing (selected) locations of LHS and RWIS stationary meteorological stations. RWIS stations are installed in the locations of various microclimates, close to the road in order to avoid too optimistic or pessimistic results.

4. Theoretical and Practical Use of Research Data for Designing, Constructing and Maintaining Roads in Lithuania

Temperature is one of the main factors affecting road design, construction and maintenance. Frozen ground is important for the design, construction and use of engineering networks, roads and other urban structures. Frozen ground in the process of its formation and vanishing changes the structure of soil, influences the circulation of surface and ground waters and the like. Thus, research and analysis of the variation of the depth of frozen ground are important from the theoretical as well as practical point of view. The temperature and the depth of frozen ground depend on climatic factors, type and mechanical composition of soils, humidity, vegetation and snow cover.

Most frequently, subgrade soils do not meet the existing soil properties of a particular location since the soils are mixed during a technological process of erecting subgrade. On the same road different type of soils can occur, having different characteristics, therefore, when designing and reconstructing roads different sources of frozen ground data are used suitable for the regioning of the territory of Lithuania.

When designing and reconstructing a road structure the best solution is to use data on the maximum depth of frozen ground from RWIS stations. Based on RWIS data Lithuania is regioned into 4 zones – when the depth of frozen ground is up to 0,8 m, up to 1,0 m, up to 1,2 m and more than 1,2 m (Fig. 3).

Fig. 3. Distribution of the maximum depth of frozen ground in the territory of Lithuania based on RWIS data

From the road maintenance point of view the most significant factors in winter are precipitation (snow), snowstorm and freezing rain. The performed analysis shows that each region should be attributed the climatic coefficient k_i based on which the quantities of works and the funds allocated to winter service enterprise would be identified. This coefficient would depend on the thickness of snow cover, number of days with glazed frost and snowstorms, duration of snowstorms. The climatic coefficient is calculated by the formula:

$$k_i = \frac{a_i}{a_v}, \qquad (6)$$

where a_v – average value of the studied characteristic; a_i – the value of the studied characteristic in a particular location (zone).

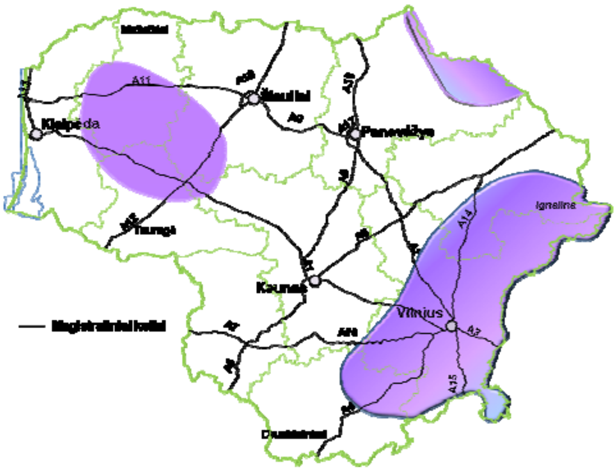

Fig. 4. General map of all climatic coefficients

Having calculated climatic coefficients for the territory of Lithuania (snow cover thickness; duration of freezing rain, in hours; duration of snowstorms, in hours) the picked out zones (Fig. 4) indicate that the highest costs for winter maintenance are required by the roads of Samogitian (Žemaičių) Highland and the south-eastern part of Lithuania.

General Conclusions

1. The implemented analysis of scientific literature on the subject of climate researches allows us to state that the development of industry caused a necessity to develop climatology trends of application character: aviation, roads, etc. Based on the review of climatic peculiarities of our country which is a coastal country but having not a typical coastal climate, one could notice many regional peculiarities, thus, it could be stated that it is not enough for Lithuania to be attributed to the climatic zone II according to a general East European climate and road regioning, it is suggested to make the regioning of Lithuania from the road construction point of view.

2. The review of territorial regioning methods shows that the regioning methods of other countries are very specific due to climatic peculiarities and different conditions of weather regime in each country. Road organizations/services of many countries when solving the tasks of road construction use the maps of multi-year data developed by meteorological services. The countries where weather conditions in a cold period of the year cause many problems on roads for the organization of maintenance works create separate maps based on the climatic factors topical for each country.

3. The implemented analysis of the effect of climatic factors on road construction indicates that already in a design stage it is necessary to make a comprehensive study of climatic conditions in the location of future road. When designing road pavement structure it is necessary to take into consideration not only the average climatic factors for the whole Lithuania but also for the region where the road is designed. When designing road pavement structure, especially a frost-blanket course, it is important to analyze not only local soil and the depth of laying ground water but also to know the size and duration of a negative temperature and the depth of frozen ground in that particular location.

4. Due to a large amount of accumulated RWIS data to be processed the database management system *MS Access* was chosen. Within the environment of this database the RWIS sub-program was created which allows us to systemize data, to obtain various derivative indices, to carry out a direct graphical data generation in the environment of the database management system itself.

5. Subject maps, made according to RWIS data, can be used by all users but for the road enterprises involved in road construction works they are especially topical: data from the maps of the depth of frozen ground and freezing cycles of pavement surface are recommended to be used for predicting pavement defects; the maps of wind speed and direction – for forecasting road sections to be covered with snow; air temperature maps – for organizing construction works and the like.

6. The map with frost impact zones is suggested to correct the thickness of structural pavement layer, defined in the Design Regulations KPT SDK 07, when designing or reconstructing roads.

7. Climatic coefficient(s) is(are) suggested (of snow cover thickness, duration of freezing rain and snowstorms, in hours) based on which the quantities of winter maintenance works and their costs could be corrected. The zone where the value of climatic coefficient is higher than 1 show that the zone has more frequent unfavourable weather conditions for road maintenance.

List of Published Works on the Topic of the Dissertation

In the reviewed scientific periodical publications

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About the author

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LIETUVOS KLIMATO ĮTAKOS KELIŲ TIESYBAI VERTINIMO METODIKA IR KLIMATINIS RAJONAVIMAS

Mokslo problemos aktualumas. Lietuva priklauso šalims, kurios jaučia didelę klimato sąlygų įtaką kelių projektavimui, tiesimui, taisymui ir priežiūrai. Automobilių kelius, be transporto priemonių krūvio, nuolat veikia daugybė klimato veiksnių. Tokios oro sąlygos, kaip nelauktas vėjas, sniegas, pūga su plikledžio apraiškomis, oro temperatūros skirtumai vasarą ir žiemą, ne tik pakeičia kelio dangos būklę, bet ir neigiamai veikia automobilio darbą, vairuotojo reakciją. Mūsų šalyje 3–4 mėnesius per metus oro temperatūra laikosi žemiau 0 °C. Ilgiausiai šis laikotarpis trunka Rytų Lietuvoje, o trumpiausiai – Pajūryje. Vidutiniškai jau lapkričio antroje pusėje susidaro pirmoji sniego danga ir išsilaiko iki kovo vidurio. Žiemą Lietuvoje dažni atlydžiai, temperatūra per parą svyruoja apie nulį, didelė lijundros, plikledžio, rūko tikimybė. Nežiūrint į didelę orų kaitą, vis dėlto pastebime tam tikrus dėsningumus, būdingus regionui. Pačius bendriausius Lietuvos klimato bruožus lemia vietos geografinė platuma, saulės radiacija, atmosferos cirkuliacija ir šių veiksnių sąveika su žemės paviršiumi.

Visa Rytų Europos teritorija pagal hidroterminio režimo dėsningumus skirstoma į penkias kelių klimato zonas, Lietuvos teritorija priskirta antrai kelių klimatinei zonai, tačiau projektuojant, tiesiant ar prižiūrint kelius reikėtų atsižvelgti ne tik į vidutinius visai Lietuvai klimato rodiklius, bet ir detaliai išnagrinėti artimiausių tam keliui meteorologinių stočių bei kelių oro sąlygų informacinės sistemos duomenis. Pagal būdingiausias oro sąlygų charakteristikas Lietuvos teritorija surajonuota į rajonus ir parajonių, šis klimatinis rajonavimas labiau geografinis. Šių rajonų nesieja vienas ar kitas klimatinis rodiklis, todėl bandymas Lietuvos teritoriją rajonuoti pagal klimatinius veiksnius kelių tiesybos požiūriu pageidautina.

Klimato, ar kitaip – orų sąlygų, prognozė – svarbi informacija pasaulio šalių kelių organizacijoms, priežiūros tarnyboms ir vartotojams.

Kelių tiesybai svarbūs klimatiniai rodikliai yra oro temperatūra ir jos perėjimų per 0 °C skaičius, grunto įšalo gylis, kritulių kiekis, jų intensyvumas, pūgų skaičius ir jų trukmė, duomenys apie lijundras.

Šiame moksliniame darbe analizuojami Lietuvos Hidrometeorologijos tarnybos (LHMT) ir Kelių oro sąlygų informacinės sistemos (KOSIS) fiksuojami klimatiniai rodikliai.

Įvertinant visus klimato ypatumus, darbo problema išskiriama tokiais punktais:

- nustatyti, ar Lietuvos teritorijos klimato skirtumai turi įtakos kelių tiesimo, taisymo ir priežiūros darbams;
- ar Lietuvai pakanka šiuo metu įteisintos vienos klimatinės zonos.

Atsakius į šiuos klausimus, nustatyti klimatinių veiksnių pasiskirstymą Lietuvos teritorijoje ir pasiūlyti jos rajonavimą kelių projektavimo, tiesimo, taisymo ir priežiūros požiūriu.

Tyrimų objektas – klimatiniai veiksniai, darantys įtaką automobilių kelių tiesybai. Eksperimentinis objektas – KOSIS (1999–2008 m.) ir LHMT (1961–1990 m.) fiksuojami parametrai.

Darbo tikslas ir uždaviniai – sudaryti Lietuvos Respublikos teritorijos klimatinį rajonavimą automobilių kelių tiesybos požiūriu.

Darbo tikslui pasiekti reikia išspręsti šiuos uždavinius:

1. Išanalizuoti ir įvertinti užsienio šalių patirtį rajonuojant teritoriją kelių tiesybos požiūriu.
2. Atlikti Hidrometeorologijos tarnybos stočių ir KOSIS fiksuojamų duomenų parametrų analizę bei palyginimą.
3. Nustatyti didžiausias ir mažiausias įšalo gylio, oro ir kelio dangos paviršiaus temperatūras.
4. Sudaryti įšalo gylių rajonus (žemėlapius) atsižvelgiant į įtakojančius veiksnius.
5. Sudaryti vėjų rožių žemėlapius, įvertinant įtakojančius veiksnius.
6. Sudaryti užšalimo ir atšilimo ciklų (perėjimų per 0 °C) žemėlapius, atsižvelgiant į įtakojančius veiksnius.
7. Nustatyti atskirų veiksnių (pūgų, sniego storio, lijundrų) įtaką kelių priežiūros organizavimui šaltuoju metu išvedant klimatinius koeficientus.

8. Įvertinus klimato veiksnius projektuojant, tiesiant ir prižiūrint kelius, pasiūlyti Lietuvos rajonavimo įgyvendinimo galimybes kelių tiesybos požiūriu.

Tyrimų metodika. Siekiant įgyvendinti darbo tikslą, taikyti tokie tyrimo metodai, kaip statistinė analizė (aprašomoji statistika), duomenų lyginimas, grupavimas, detalizavimas, apibendrinimas ir grafinis jų atvaizdavimas taikant paviršiaus interpoliavimo metodą – *krigingo* metodą.

Buvo atlikta Lietuvos ir kitose užsienio šalyse taikomų klimatinio rajonavimo metodikų analizė. Statistiniai ir lyginamosios analizės metodai taikyti analizuojant klimato veiksnių duomenis, gautus iš LHMT ir KOSIS. Išanalizuoti daugiamečiai (1961–1990 m.) LHMT ir 1999–2008 m. KOSIS stočių grunto įšalo, oro temperatūros, kritulių, vėjo ir kt. duomenys.

Didžiuliam kiekiui duomenų apdoroti buvo pasirinkta duomenų bazių valdymo sistema *MS Access*. Meteorologinių stotelių duomenys papildyti stotelių koordinatėmis, perskaičiuotomis iš elipsoidinių į plokštumines, tokia informacija leido pažymėti stoteles geografinėse informacinėse sistemose (GIS) ir, pasitelkus AutoCad Civil 3D programą, kurti teminius Lietuvos žemėlapius.

Mokslinis naujumas

Pirmą kartą atliekamas teritorijos rajonavimas kelių tiesybos požiūriu, pasitelkiant KOSIS fiksuojamų duomenų parametrus bei įvertinant svarbiausius veiksnius: įšalo gylį, oro temperatūrą, užšalimo ir atšilimo ciklus bei vėjo greitį ir kryptį.

Klimatinio rajonavimo požiūriu atskiras teritorijas galima charakterizuoti turint ne mažiau kaip 7 metų istorinius klimato rodiklius. KOSIS duomenis fiksuoja jau nuo 1999 m., tai klimatinį kelių rajonavimą pagal skirtingus klimato veiksnius daryti yra tikslinga ir galima gauti patikimus rezultatus.

Mokslo darbe atlikus klimatinių veiksnių analizę siūlomas klimatinis koeficientas atskiroms Lietuvos zonoms, į kurį atsižvelgus būtų galima tikslinti darbų kiekius bei kelių tarnyboms skiriamas lėšas kelių priežiūrai žiemą. Šis koeficientas priklausytų nuo sniego dangos storio, dienų su lijundra ir pūgomis skaičiaus, pūgų trukmės. Be to, atsižvelgiant į šalčio poveikio pasiskirstymo zonų žemėlapį, siūloma tikslinti dangų konstrukcijos storio parinkimą.

Praktinė vertė. Šios disertacijos tema aktuali kelių organizacijoms ir tarnyboms bei komunalinininkams praktiniu aspektu. Atlikta analizė ir gauti rezultatai padės lengviau išspręsti kelių projektavimo, tiesimo, taisymo ir priežiūros klausimus Lietuvoje, įvertinant klimato veiksnių įtaką.

Ginamieji teiginiai

1. Lietuvos teritorijos klimato nevienalytiškumas vertinamas kelių tiesybos požiūriu.
2. Klimato veiksniai, turintys įtaką kelių projektavimui, tiesimui ir priežiūrai.
3. Turimi KOSIS duomenys papildo ir patikslina LHMT duomenis, be to KOSIS duomenų pagrindu sudaromas tikslesnis (įšalo gylio, dangos paviršiaus užšalimo/atšilimo ciklų, vėjo greičio ir krypties, oro temperatūros) rajonavimas, kuris palengvina kelius projektuojančių, tiesiančių, taisančių ir prižiūrinčių įmonių veiklą.
4. Lietuvos klimatinis rajonavimas pagal klimato parametrus, įtakojančius kelių tiesybos procesus.
5. Siūloma įvesti klimatinį koeficientą, kurį taikant būtų galima vertinti priežiūros darbų kiekius ir tikslinti sąnaudas žiemą.

Darbo apimtis. Darbą sudaro bendra darbo charakteristika, keturi skyriai, išvados, literatūros sąrašas, publikacijų sąrašas ir priedai. Bendra disertacijos apimtis – 127 puslapiai, 74 iliustracijos, 5 lentelės ir 4 priedai.

Pirmame disertacijos skyriuje analizuojama mokslinė literatūra apie klimatą, jo kaitą, klimato veiksnių poveikį, klimatinį rajonavimą. Taip pat apžvelgiamas Lietuvos klimatas ir jo veiksnių įtaka automobilių kelių tiesybai.

Antrame disertacijos skyriuje atlikta klimatinio rajonavimo metodų analizė. Išnagrinėti klimato veiksniai, kurie daro įtaką kelių projektavimui, tiesimui, taisymui ir priežiūrai. Įvertinta, kad Lietuvai nepakanka šiuo metu įteisintos vienos klimatinės zonos, ir, kad Lietuvos teritorijos rajonavimas kelių tiesybos požiūriu pageidautinas.

Trečiame disertacijos skyriuje buvo atlikta Hidrometeorologijos tarnybos ir Kelių oro sąlygų informacinės sistemos tyrimų metodų analizė bei HMT daugiamečių (1961–1990 m.) ir KOSIS (1999–2008 m.) duomenų analizė bei vertinimas.

Ketvirtame disertacijos skyriuje pateikiamas siūlymas Lietuvos teritoriją rajonuoti pagal įšalo gylį, šalčio poveikį, dangos paviršiaus užšalimo/atšilimo ciklų skaičių, vėjo greitį ir kryptį bei klimatinį koeficientą bei pasiūlytos rajonavimo galimybės kelių tiesybos požiūriu.

Bendrosios išvados

1. Atlikta mokslinės literatūros klimato tyrimų tema analizė leidžia teigti, kad vystantis ekonomikai, atsirado būtinybė plėtotis taikomojo pobūdžio klimatologijos kryptims: aviacijos, kelių ir kt. Apžvelgus mūsų šalies, kuri yra pajūrio kraštas, tačiau klimatas nėra tipiškai jūrinis, klimato ypatumus,

pastebima daug regioninių išskirtinumų, todėl galima teigti, kad Lietuvai neužtenka būti priskirtai II klimatinei zonai pagal bendrą Rytų Europos klimatinį ir kelių rajonavimą, siūloma sudaryti Lietuvos rajonavimą kelių tiesybos požiūriu.

2. Atlikus teritorijų rajonavimo metodų apžvalgą galima teigti, kad kitose šalyse taikomi rajonavimo metodai turi savo specifiką dėl kiekvienos šalies klimatinių ypatumų ir skirtingų oro rėžimo sąlygų. Daugelio šalių kelių organizacijos ir tarnybos, spręsdamos kelių tiesybos uždavinius, remiasi meteorologijos tarnybų sudarytais žemėlapiais iš daugiamečių duomenų. Šalys, kurių oro sąlygos šaltojo sezono metu kelia daug problemų keliuose, priežiūros darbams organizuoti sudaro atskirus žemėlapius iš aktualių kiekvienai šaliai klimato veiksnių.

3. Atlikta klimato veiksnių įtakos kelių tiesybai analizė rodo, kad dar projektavimo stadijoje turi būti išsamiai išnagrinėtos klimato sąlygos būsimo kelio vietovėje. Projektuojant kelio dangos konstrukciją, būtina atsižvelgti ne tik į vidutinius visai Lietuvai, bet ir tam rajonui, kuriame projektuojamas kelias, būdingus klimato veiksnius. Projektuojant kelio dangos konstrukciją, ypač apsauginį šalčiui atsparų sluoksnį, svarbu išanalizuoti ne tik vietinio grunto rūšį, gruntinio vandens slūgsojimo gylį, bet ir žinoti neigiamos oro temperatūros dydį bei trukmę bei įšalo gylį toje vietovėje.

4. Esant dideliam sukauptam KOSIS duomenų kiekiui, juos apdoroti buvo pasirinkta DBVS *MS Access*. Šios duomenų bazės terpėje buvo sukurta KOSIS DB paprogramė, kuri leidžia susisteminti duomenis, gauti įvairius išvestinius rodiklius, atlikti tiesioginį grafinį duomenų generavimą pačioje DBVS aplinkoje.

5. Sudarytais iš KOSIS duomenų teminiais žemėlapiais gali naudotis visi vartotojai, tačiau kelių tarnyboms, atliekančioms kelių tiesybos darbus, jie yra ypač aktualūs: įšalo gylio, kelio dangos paviršiaus užšalimo ciklų žemėlapių duomenis rekomenduotina naudoti prognozuojant dangos konstrukcijoje susidarančius defektus; vėjo krypties ir greičio žemėlapius – prognozuojant galimus užpustomų kelių ruožus; oro temperatūros žemėlapius – organizuojant tiesimo darbus ir pan.

6. Pasiūlytas žemėlapis su šalčio poveikio zonomis siekiant patikslinti KPT SDK 07 projektavimo taisyklėse dangų konstrukcijos sluoksnio storį projektuojant ar rekonstruojant kelią.

7. Pasiūlytas (-i) klimatinis (-iai) koeficientas (-ai) (sniego dangos storio, lijundros ir pūgų trukmės, valandomis), pagal kurį (-iuos) būtų galima tikslinti priežiūros darbų kiekius bei sąnaudas žiemą. Toji zona, kurioje klimatinio koeficiento vertė didesnė už 1, rodo, kad joje nepalankios kelių priežiūrai oro sąlygos pasitaiko dažniau.

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Padėka

Dėkoju darbo vadovui, Kelių katedros vedėjui prof. dr. Alfredui Laurinavičiui, Aplinkos inžinerijos fakulteto dekanui prof. dr. Donatui Čygui ir visiems kolegoms bei draugams už patarimus bei pagalbą rašant šią daktaro disertaciją. Taip pat norėčiau padėkoti savo artimiesiems už palaikymą, supratimą ir kantrybę.