ROAD-CLIMATE ZONING FOR WATER-THERMAL MODE REGULATION IN TRANSPORT STRUCTURES

[1]*Associate Professor **Olena Usichenko***
[2]*Alina Kvatadze*

[1]*Ukraine, Kyiv, National Transport University,*
Professor of Transport Construction and Property Management Department;
[2]*Ukraine, Kyiv, State Road Agency of Ukraine,*
Senior Specialist of the Department Intelligent Transport Systems

ABSTRACT

The article considers the problems of road-climatic zoning of the territory of Ukraine. The shortcomings of the existing system and the need to update and improve it were justified. The purpose of work was formed and realized taking into account modern approaches to meteorological data processing and segmentation methods. The study is based on long-term observations of weather conditions throughout the country. Using the moisture-thermal regime calculation and analytical system, the collected static meteorological information was processed and tables of the initial data for further analytical processing were obtained. The paper describes the methodology of cluster analysis using as the main tool for the typification of territories and the allocation of morphologically homogeneous humid areas. The result of the work was the elaboration of a road and climatic zoning map under the wetting conditions of the road subgrade working layer.

Introduction. The need to improve road-climatic zoning and to develop recommendations on the application of climatic characteristics and climatic zoning of the territory of Ukraine for road construction is due to the fact that these issues were developed back in 70-80 years of the last century using data on climatic conditions throughout the territory of the former USSR. Global climate change (warming) on the planet has changed the amount of atmospheric humidity. As a consequence, the elements of the road structure are subject to increased precipitation effects, which leads to a change of the whole structure water-thermal regime (WTR). Moistening of the road structure is the main cause of destruction and deformation. Approaches to the design of WTR regulation structures should vary according to the external influences intensity. Drainage systems designing requires to updating, methodological regulation, taking into account the modern meteorological information, and obtaining special meteorological values databases that are estimated value in road construction elements designing procedure.

The problems of the recent years changes climatic factors influence on the road construction based on meteorological data of the Lithuanian Hydrometeorological Service (LHS) were reflected in the climatic zoning of the Republic of Lithuania territory in [1, 2]. The grouping of precipitation by their level using statistical methods and based on cluster analysis for the Poland temperate climate is presented in [3].

The important role of clustering as a convenient and accurate method for data segmentation and analytics has been analyzed in [4]. According to the cluster analysis algorithm, using a map of different spatial data sets and software capabilities, a map with selected homogeneous hydrological zones was constructed [5].

Research results. Currently, the valid regulatory document setting the climatic parameters for the design of civic, industrial buildings and structures, heating, ventilation, air conditioning, water supply, in the planning and construction of urban and rural settlements is DSTU-N B V.1.1-27:2010. The available data are insufficient for road-climatic zoning, as only average rainfall values are provided for regions. However, soil and hydrological conditions and freezing depth are not taken into account, although it is one of the most important climatic indicators in road climatology. In view of the above, the purpose of the study was formulated: to develop a map of road and climatic zoning of the Ukraine territory under conditions of wetting with atmospheric precipitation on the basis of climate zoning methods.

Zoning is a complex process as it takes into account not only the elements of climate, hydrology and soil conditions. Road-climatic zoning of the Ukraine territory is enshrined in DBN B.2.3-4 2015 "Highways" and differentiates the norms of transport structures designing and construction. According to landscape-geographical zoning, soil-hydrologic and wetting conditions, as well as experience of road operation, the territory of Ukraine is divided into four climatic zones: northern, central, southern and mountainous. It should be noted that the existing road-climate zoning reflects only the general dependence of road design and construction on climate and most other natural conditions, and is therefore schematic. In the process of road designing, it is important not to limit the general characteristics of the climatic conditions obtained by assigning the area of the route to the relevant zone, but to study with sufficient detail the climate elements according to the data of local meteorological stations.

In order to improve the normative support and to form the meteorological characteristics databases for WTR regulation structure design needs the methods of meteorological information processing, existing meteorological data were analyzed and generalized, the analysis and estimation of the statistical meteorological information required volume were carried out. On the basis of the analysis, the collection of statistical meteorological information for ten years at thirty-eight meteorological stations of Ukraine was performed, and the obtained meteorological data sets were analyzed. Using the available calculation and analytical system, the statistical processing of the obtained arrays of meteorological information was performed. In the process of developing a methodology of climatic characteristics application for the construction needs, the shortcomings of the calculation and analytical system (WTR) used for statistical processing of meteorological information were identified. The calculation apparatus was brought to the required level and the information base was updated.

Results and Discussion. Road-climatic zoning takes into account not only the natural and climatic characteristic, but also the features of road construction and maintenance. The basis of road-climatic zoning should be based on the distribution of heat and moisture - the wet-thermal regime of the terrain.

Based on collected data from meteorological stations (Askaniya-Nova, Berdyansk, Bila Tserkva, Bolhrad, Vinnytsya, Dnipropetrovsk, Donetsk, Druzhba, Zhytomyr, Zaporizhia, Kerch, Kyiv, Kirovohrad, Kovel, Lubny, Luhansk, Lutsk, Lviv, Melitopol, Mykolayiv, Mizhhirya, Ovruch, Odesa, Pervomaysk, Poltava, Pryluky, Rivne, Simferopol, Sumy, Ternopil, Uzhhorod, Uman, Kharkiv, Kherson, Khmelnytskyi, Cherkasy, Chernivtsi, Chernihiv) climatological characteristics of precipitation, snow cover and air temperature were analyzed, tables of data on average and extreme values were calculated and formed. By means of the calculation and analytical system "WTR" graphs of temperature course for a ten-year period and periods of wet-thermal regime of road construction have been developed. The snippet of the program window is shown in Fig. 1.

РІК РОЗРАХУНКУ	1	2	3	4	5	6	7	8	9	10	11	12	ПОЧАТОК ВЕСНЯНОГО РОЗРАХУНКОВОГО ПЕРІОДУ - Перехід через 0	ПОЧАТОК ОСІННЬОГО РОЗРАХУНКОВОГО ПЕРІОДУ - перехід температури через +10	ПОЧАТОК ЗИМОВОГО РОЗРАХУНКОВОГО ПЕРІОДУ - прехід через -5	Період замерзання, доба	ПОЧАТОК ЛІТНЬОГО РОЗРАХУНКОВОГО ПЕРІОДУ - Кінець розмерзання
2006	-8,2	-8,0	-1,7	8,4	13,7	18,0	20,1	19,2	14,6	8,6	2,1	1,7	18.03.2006	10.10.2006	01.01.2006	76	26.04.2006
2007	0,7	-6,5	5,4	7,5	17,0	19,7	20,2	20,7	13,8	8,5	-0,1	-0,9	01.03.2007	08.10.2007	09.02.2007	20	22.03.2007
2008	-3,7	-0,5	3,6	10,3	17,0	19,7	20,2	20,7	13,8	8,5	-0,1	-0,9	-	09.10.2008	-	0	15.04.2008
2009	-4,5	-3,0	1,3	9,6	14,1	19,2	20,6	17,8	16,2	7,8	4,0	-4,6	-	07.10.2009	-	0	15.04.2009
2010	-11,0	-4,4	-0,5	9,1	17,1	21,1	24,3	23,4	13,9	5,4	6,3	-5,3	16.03.2010	28.09.2010	17.12.2009	89	21.04.2010
2011	-3,7	-7,8	-0,5	9,0	15,8	20,2	21,4	18,5	14,0	6,6	1,7	1,3	17.03.2011	02.10.2011	14.12.2010	93	23.04.2011
2012	-5,1	-11,9	1,2	10,6	17,4	18,5	22,2	19,2	14,7	8,8	4,0	-5,9	13.03.2012	12.10.2012	15.01.2012	58	20.04.2012
2013	-5,5	-1,4	-3,0	9,1	18,4	21,1	19,8	18,9	12,4	8,6	5,8	-1,0	21.03.2013	05.10.2013	13.12.2012	98	20.04.2013
2014	-6,2	-1,4	5,8	9,6	16,7	17,4	21,5	19,8	13,6	5,5	1,2	-2,7	21.03.2014	28.09.2014	09.01.2014	71	09.04.2014
2015	-1,4	-1,4	4,3	8,4	15,1	19,1	19,8	20,5	16,4	5,3	3,6	1,2	-	03.10.2015	-	0	15.04.2015

Fig. 1. The results of the WTR periods calculation

The tables of rainfall intensity and depth of soil freezing estimated values for different zones of the road base were calculated and formed on the basis of the obtained data, (Fig. 2).

														m_{cp}	6,5714
														MAXy	
№пп	Рік	m_{cp} середня кількість дощів	T_{∂}, хв. сумарна тривалість опадів, хв.	S, мм сумарна кількість опадів за період	t_{r} температура поверхні грунту	f відносна вологість повітря	d, мбар Дефіцит вологості повітря	Ранг			Flag			$P_{\ni}$			$T_{\partial(cp)}$, хв.	465,6
1	2006	13	1392	53,7	3,25	78,25	1,42552	7	1	1	1	1	1	90,54	10,94	10,94	95	5
2	2007	6	432	13,4	4	69,7	1,98546	3	5	5	1	1	1	36,49	73,44	73,44	d0, мбар	
3	2008						0	0	0	0	0	0	0				5	2,3915
4	2009						0	0	0	0	0	0	0				95	1,3949
5	2010	5	336	7,6	2,3	75	1,63901	6	6	6	1	1	1	77,03	89,06	89,06	T_{∂}, хв.	
6	2011	8	1008	19,2	4	67,8	2,10996	2	2	4	1	1	1	22,97	26,56	57,81	5	1380,3
7	2012	11	912	36	3,3	73,7	1,72371	5	3	2	1	1	1	63,51	42,19	26,56	95	171,69
8	2013	3	576	22,9	1,3	70,3	1,94773	4	4	3	1	1	1	50	57,81	42,19	S, мм	
9	2014	0	0	0	9	63	2,42093	1	0	0	1	0	0	9,459			5	50,317
10	2015						0	0	0	0	0	0	0				95	0,6164

Fig. 2. Calculation of precipitation regime of 5% security.

The results obtained were used for the climatic zoning of the Ukraine territory. Namely, a cluster analysis tree was built based on the following indicators: average rainfall 5% security (mm), average monthly temperature in July and average monthly temperature in January. Thus, the necessary climate parameters used in the project practice are covered.

Considering convenience and testing of clustering [4, 5], for building a cluster tree the software complex STATISTICA was used to construct the cluster tree. This software is intended for comprehensive statistical analysis. The STATISTICA package implements procedures for data analysis, data management, data retrieval and visualization. It implements the classic methods of cluster analysis, including k-means, hierarchical clustering, and two-input joins. The data can come in the original form as well as in the form of a matrix of distances between objects. Observations and variables can be clustered using different distance measures (Euclidean, Euclidean square, Manhattan, Chebyshev, etc.) and different clustering rules (single, complete, unweighted and weighted pairwise, group average, etc.).

In the case of road-climatic zoning, hierarchical clustering was used. At first, tree diagrams may seem a bit confusing, but after some study they become more understandable. The chart starts from the top (for a vertical dendrogram) with each weather station in its own cluster. When moving down, the weather stations that "closely touch each other" unite and form clusters. Each chart assembly shown in Figure 3, represents a combination of two or more clusters, the position of the nodes on the vertical axis determines the distance at which the corresponding clusters were combined.

As a result of the construction of a cluster analysis tree according to the indicators of average rainfall intensity 5% − the territory of Ukraine was divided into 3 groups. In group A with the highest average precipitation intensity 5% (13-15 mm) − Uman, Priluki, Poltava, Melitopol, Kovel, Chernivtsi, Ternopil, Rivne, Lutsk, Chernigov, Ovruch, Lubny, Sumy, Druzhba.

Group B united such meteorological stations as Pervomaysk, Zaporizhia, Melitopol, Simferopol, Kerch, Bolgrad, Kherson, Askania-Nova, Dnepr, Lviv. The average intensity of precipitation according to their data is from 10 to 12 mm.

The group C includes meteorological stations on a low level of average intensity of precipitation (6-10 mm), as Uzhgorod, Odessa, Nikolaev, Kirovograd, Kharkov, Lugansk, Donetsk, Kiev, Vinnitsa, Khmelnitsky, Zhitomir and White Church.

38 stations of Ukraine were also selected for clustering according to the indices of specific excess moisture entering the drainage structure. The analysis was performed in eight-dimensional space. The main types of regions were identified (Fig. 5).

The results obtained in the STATISTICA software were entered as the source data in the GIS MapInfo software for building a road-climate map. As a result, the above-mentioned indicator was divided into 5 zones, which are not evenly distributed. Their number varies depending on the geographical location of the area (Fig. 6).
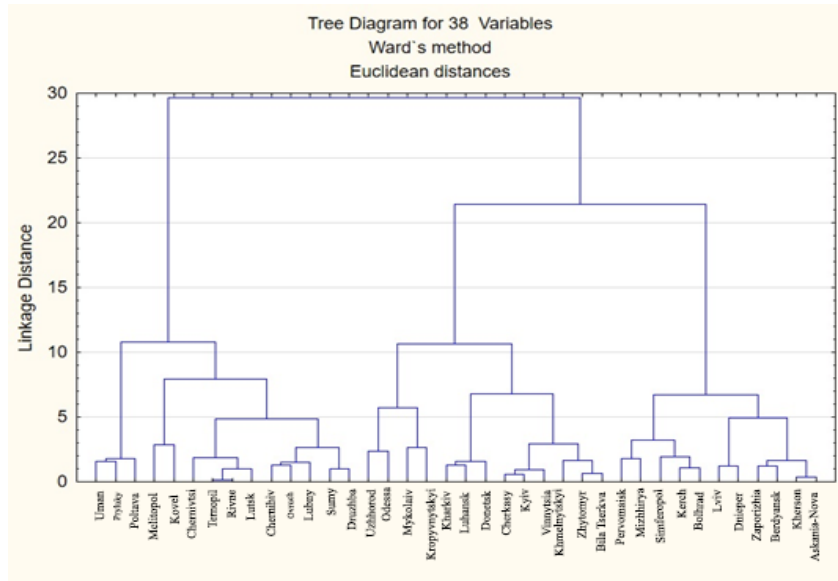
Fig. 3. Cluster tree with average rainfall intensity of 5% security.

Fig. 4. Map of road-climatic zoning of the Ukraine territory by average rainfall indicators
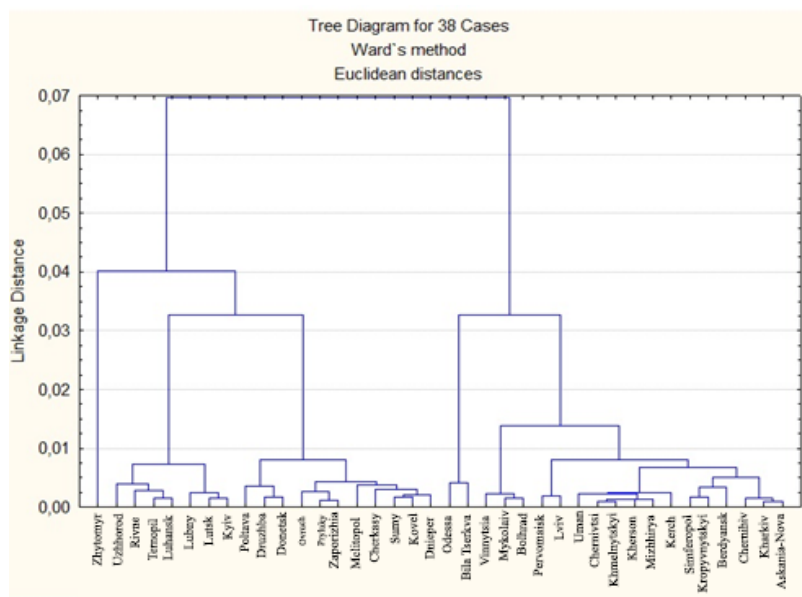

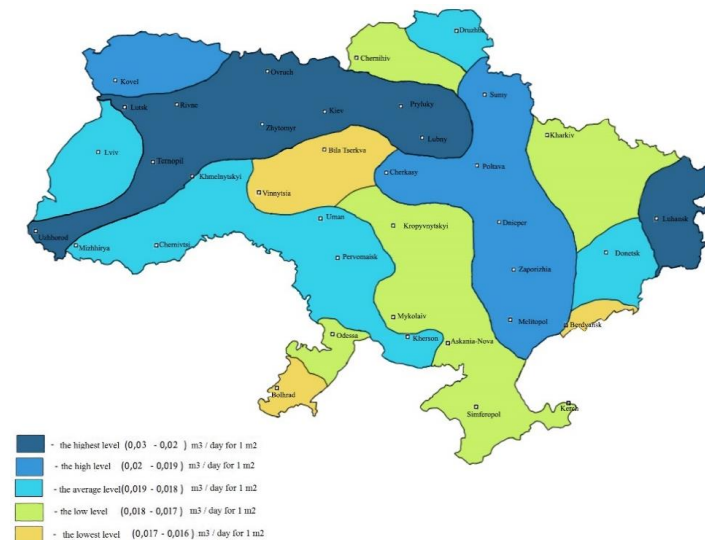*Fig. 5. Cluster tree in terms of specific excess water entering the drainage structure.*

Fig. 6. Map of road-climatic zoning of the Ukraine territory by the specific excess water entering the drainage structure values

Conclusions. Cluster analysis refers to statistical and modeling software systems. Statistical packages have advanced cluster analysis modules to use geographic information to divide objects into groups.

Clustering of territorial units is used for the tipization of the territory and modeling of system-forming connections. On the basis of cluster analysis on the value of specific excess of water entering the drainage structure, a map of road-climatic zoning of the territory of Ukraine was developed in the basis of road clothes. According to the signs of moisture entering the drainage of the shallow construction of the road construction, the territory of Ukraine is divided into 5 zones. On the map of zoning, zones with different levels of total specific excess of water (infiltration and defrosting, from the lowest to the highest level) are allocated. The distribution of zones takes into account both the geographical position of the terrain, and the features of infiltration of atmospheric precipitation, the depth of soil frozen and moisture accumulation in road structures of all technical categories.

On the basis of the result of the work performed − statistical processing and execution of complex calculations, the "Directory of climatic characteristics and climatic zoning of the territory of Ukraine for the regulation of water-heat regime in road construction" was developed. Work is now under way to develop an electronic database of indicators and to develop an improved accounting and analytical system. The purpose of further work is to simplify the use of the obtained indicators and automate the process of designing regulatory structures.

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