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ROMAN I. KINASH[*], JAROSLAV S. HUK[**]

GEOGRAPHICAL ALTITUDE COEFFICIENT UTILISATION FOR WIND GUST LOADING DETERMINATION IN THE MOUNTAINOUS TERRAIN OF THE TRANSCARPATHIAN REGION

WYKORZYSTANIE WSPÓŁCZYNNIKA WYSOKOŚCI GEOGRAFICZNEJ DO OBLICZANIA ODDZIAŁYWANIA WIATRU NA TERENACH GÓRSKICH REGIONU ZAKARPACIA

A b s t r a c t

This paper presents the method and results of a geographical altitude factor calculation to determine wind loading C_{alt} at 9 meteorological stations in the Transcarpathian region. According to state building standards B.1.2-2:2006, the coefficient of geographical altitude is used to calculate wind pressure while positioning the building site at an altitude of up to 0.5 km it equals 1, at altitudes higher than 0.5 km, it is determined using the formula $C_{alt} = 4H–1$. With the help of the suggested method, according to 23 directions and high wind coefficients, as well as data of meteorological observations from 1955–2005, the coefficients of geographical altitude were calculated to determine wind loading in July and January for each residential site, the peaks and mountain passes for the Transcarpathian region of Ukrainian Carpathians.

Keywords: wind load, geographical altitude factor, building construction, Transcarpathian region, meteorological station, mountainous terrain

S t r e s z c z e n i e

W artykule przedstawiono metodykę i wyniki określenia współczynnika wysokości geograficznej do obliczeń oddziaływania wiatru C_{alt} wg danych pomiarów z 9 stacji meteorologicznych Zakarpacia. Według DBN B.1.2-2:2006 współczynnik wysokości geograficznej jest wykorzystywany do obliczania parcia wiatru przy lokalizacji obiektu budowlanego: na wysokości do 500 m jest równy 1,0, a na wysokości ponad 500 m – obliczany wg wzoru $C_{alt} = 4H$-1. Z proponowanej metody dla 23 kierunków i współczynników wiatrowo-wysokościowych oraz danych meteorologicznych z lat 1955–2005 obliczono współczynniki wysokości geograficznej do określenia oddziaływania wiatru w lipcu i styczniu dla każdej miejscowości, szczytów oraz przełęczy Ukraińskich Karpat dla Obwodu Zakarpatskiego.

Słowa kluczowe: obciążenie wiatrem, współczynnik wysokości geograficznej, obiekt budowlany, region Zakarpacia, stacja meteorologiczna, tereny górskie

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[*] AGH University of Science and Technology, Krakow, Poland; Lviv Polytechnic National University, Ukraine.
[**] Uzhgorod National University, Ukraine.

1. Introduction

Wind impact, which is considered in the calculations of building construction, is determined on the basis of a wide range of interdependent values such as: wind speed, depending on climatic conditions, as well as the type of area and the altitude above it; the external shape of the building, specific architectural and constructive solutions; dynamic properties [1, 2]. Each of the described values is variable and random, and depends on a wide range of factors. Characterising and calculating loads depends on adopting liability criteria of the building units [9, 10].

Wind load is the main type of impact which is impossible to avoid compared with other types of wind impact such as disturbance vortices, flatter or galloping which can be predicted. All of these are shown in the way of one of the general correlations of characteristic value, for example, as a load which acts at a unity of surface [3].

The region of the Ukrainian Carpathians comprises almost 4% of the Ukrainian territory. It is situated almost within the geographical center of Europe. However, the construction in the Carpathian region as well as in mountainous regions overall, has its own peculiarity related to the higher levels of seismic, wind and snow loads, the possibility of floods, sills, geological landslips, avalanches etc.

Therefore, the necessity of scrutinised research and precise determination of wind load parameters for the Transcarpathian region has arisen. It is wise to mention that up to 80% of this region is comprised of mountainous areas which will be sensible to investigate with the help of the direction method using altitude, altitude and logarithmical, latitude and longitude factors and by checking the results using the method of barometric leveling [6–8].

2. Method to determine the geographical altitude factor

According to state building standards DBN B.1.2-2:2006 [4], exploitation-calculating value of the wind load, W_e, is determined with the help of the following formula:

$$W_e = \gamma_{fe} \cdot W_o \cdot C \tag{1}$$

where γ_{fe} – liability factor due to exploitation-calculating value of the wind load; W_o – characteristic value of wind pressure, Pa; C – general factor determined by:

$$C = C_{\text{aer}} \cdot C_h \cdot C_{\text{alt}} \cdot C_{\text{rel}} \cdot C_{\text{dir}} \cdot C_d \tag{2}$$

where C_{aer} – aerodynamic coefficient; C_h – coefficient of construction height; C_{alt} – coefficient of geographical altitude; C_{rel} – relief coefficient; C_{dir} – direction coefficient; C_d – coefficient of dynamics.

The characteristic value of wind pressure W_o equals the average (static) component of wind pressure at a height of 10 m above the Earth's surface which can be exceeded once every 50 years.

The characteristic value of wind pressure W_o is determined depending on the wind region on the map or due to details in appendix E [4].

Where necessary, it is acceptable to determine W_o by means of statistical processing of the results of temporary measurements of wind speed.

The geographical altitude factor of wind pressure, C_{alt}, considers the height H (km) above Baltic sea level of the positioning of the construction unit and is calculated by the following formulas:

$$C_{alt} = 4H - 1 \quad (H > 0.5 \text{ km}) \tag{3}$$

$$C_{alt} = 1 \quad (H < 0.5 \text{ km}) \tag{4}$$

Formulas (3) and (4) are used for units situated in mountainous areas and provide approximate values for liability purposes. Having the results of meteorological observations, the characteristic value of wind load is calculated by means of statistic processing of the results of temporary measurements of wind speed and adopting that C_{alt} is accepted as equal to 1.

Calculations of C_{alt} were performed for 9 meteorological stations of Transcarpathian region [1–3] utilising the base meteorological station Berehovo, situated at the lowest level of the Baltic sea (altitude – 113 m).

To estimate actual values of the coefficient $C_{alt,}$ the maximum wind loads in July and January were calculated according to the observations from 1955 to 2005 at the meteorological stations and the following formula was used:

$$C_{alt} = \frac{W_{o,st.X}}{W_{o,st.\text{Berehovo}}} \tag{5}$$

where $W_{o,st.X}$ – calculated maximum wind loads in July and January at the meteorological stations X, Pa; $W_{o,st.\text{ Berehovo}}$ – calculated maximum wind loads in July and January at the basic and the lowest altitude above the Baltic sea level at the weather station situated at Berehovo, Pa.

According to formula (4) for six meteorological stations: V. Bereznyi, Mizhgir'ya, N. Vorota, Rakhiv, Yzhgorod Hust, which are situated higher than weather station Berehovo and not more than 0.5 km, coefficient C_{alt} = 1. Due to formula (5) coefficient, C_{alt} for meteorological station Plai equals 4.08, for meteorological station N. Studeniy – 1.008, accordingly ΔH_{Plai}= 1.27 km, $\Delta H_{\text{N.Studeniy}}$ = 0.502 km.

3. The calculation results of the geographical altitude factor and wind load

Calculation results of the geographical altitude factor, C_{alt}, due to state building standards DBN B.1.2-2:2006 [4] and observational data of wind loads from 1955 to 2005 at the 9 meteorological stations of the Transcarpathian region are provided in Table 1.

Table 1

Calculation results of the geographical altitude factor, C_{alt}, due to [4] and observational data of wind loads from 1955 to 2005 at the 9 meteorological stations of the Transcarpathian region

No.	Name of weather station	Altitude above Baltic sea level	Altitude difference between Berehovo station and other weather stations	C_{alt} eqs. (3) (4)	Observations maximum wind load		C_{alt} eqs. (5)	
					July	January	July	January
		[m]	[m]		[Pa]	[Pa]		
1.	Berehovo	113	–	1	350	240	1	1
2.	V.Bereznyi	209	96	1	380	240	1.08	1
3.	Mizhgir’ya	456	343	1	740	320	2.11	1.33
4.	N.Studenyi	615	502	1.008	200	320	0.57	1.33
5.	N.Vorota	500	387	1	270	240	0.77	1
6.	Rakhiv	438	325	1	550	240	1.57	1
7.	Yzhgorod	114.6	1.6	1	410	320	1.17	1
8.	Khust	166	53	1	240	240	0.68	1
9.	Plai	1330	1270	4.08	970	970	2.77	4.04

The plots of the geographic altitude factor change C_{alt} which was calculated by formulae (3) and (4) according to [4] and formula (5) calculated according to the maximum wind loads at the meteorological stations for the observations made from 1955 to 2005 are shown in the Fig 1.

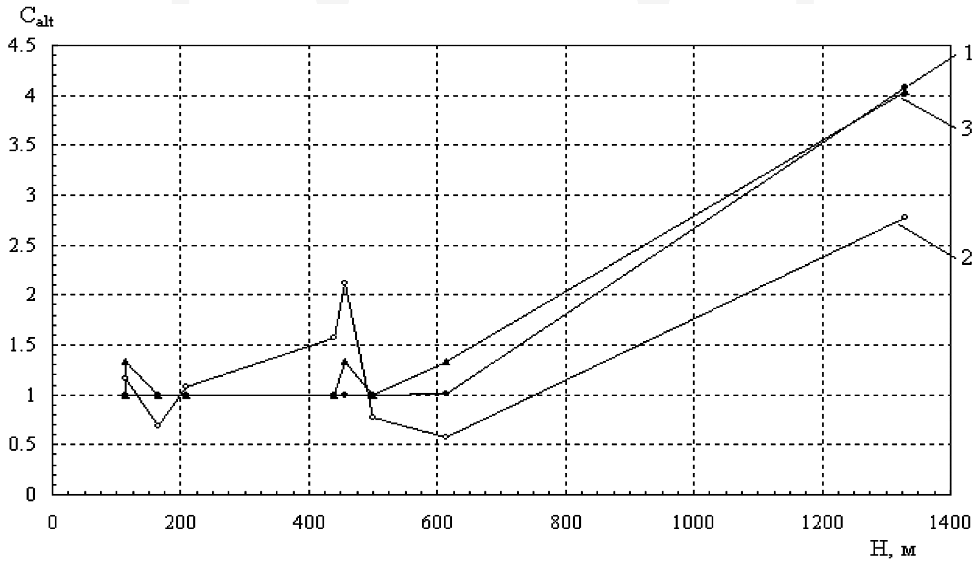

Fig. 1. Correlation between the change of geographic altitude factor C_{alt} and position of meteorological stations in the Transcarpathian region above Baltic sea level, 1 – according to eqs. (3) and (4) according to [4]; 2 – according to the results of observations in July due to formula (5); 3 – according to the results of observations in January due to formula (5)

The comparison of the values of average compound of wind pressure W_o, calculated according to the observations made from 1955 to 2005 at the 9 meteorological stations of the Transcarpathian region with the standards of building norms and rules SNiP 2.01.07-85 [5] and the state building standards DBN B.1.2-2:2006 [4] are shown in Table 2.

Table 2

Comparison of the values of average compound of wind pressure W_o

No.	Name of weather station	Altitude above Baltic sea level	Average compound of maximum wind pressure, W_o				Calculated differences between W_o, according to the observations and standard data			
			[5]	[4]	observations					
					summer	winter	[5] (summer)	[5] (winter)	[4] (summer)	[4] (winter)
		[m]	[Pa]	[Pa]	[Pa]	[Pa]	[Pa] / [%]	[Pa] / [%]	[Pa] / [%]	[Pa] / [%]
1.	Berehovo	113	480	400	350	240	-130 / -27.1	-240 /-50.0	-50 / -12.5	-160 / -40.0
2.	V.Bereznyi	209	480	450	380	240	-100 / -20.8	-240 / -50.0	-70 / -15.6	-210 / -46.7
3.	Mizhgir'ya	456	480	450	740	320	+260 / +54.2	-160 / -33.3	+290 / +64.4	-130 / -28.9
4.	N.Studenyi	615	480	450	200	320	-280 / -58.33	-160 / -33.3	-250 / -55.6	-130 / -28.9
5.	N.Vorota	500	480	450	270	240	-210 / -43.7	-240 / -50.0	-180 / -40.0	-210 / -46.7
6.	Rakhiv	438	480	450	550	240	+70 / +14.6	-240 / -50.0	+100 / +22.2	-210 / -46.7
7.	Yzhgorod	114.6	480	400	410	320	-70 / -14.6	-160 / -33.3	+10 / +2.5	-80 / -20.0
8.	Khust	166	480	400	240	240	-240 / -50.0	-240 / -50.0	-160 / -40.0	-160 / -40.0
9.	Plai	1330	480	450	970	970	+490 / +102.1	+490 / +102.1	+520 / +115.0	+520 / +115.0

Fig. 2 concludes of the change of average compound of wind pressure, W_o, due to the observations during the years from 1955 to 2005 and standards [4] and [5] depending on the altitude above Baltic sea level of 9 meteorological stations of the Transcarpathian region.

The characteristic value of wind pressure, W_o, standardised by [5] for the Transcarpathian region is 480 Pa. In comparison to the calculated statistical data at the 9 meteorological stations, according to the observations made from 1955 to 2005 in July, for six meteorological stations the actual values of maximum wind pressure W_o are raised too high within the limits of 14.6% to 58.3%; for three weather stations, W_o values are set too low within the limits of 14.6% to 102.1%; in January, for 8 meteorological stations, W_o values are raised too high within the limits of 33.3% to 50.0%; for the weather station Plai, W_o values are set too low at 102.1%.

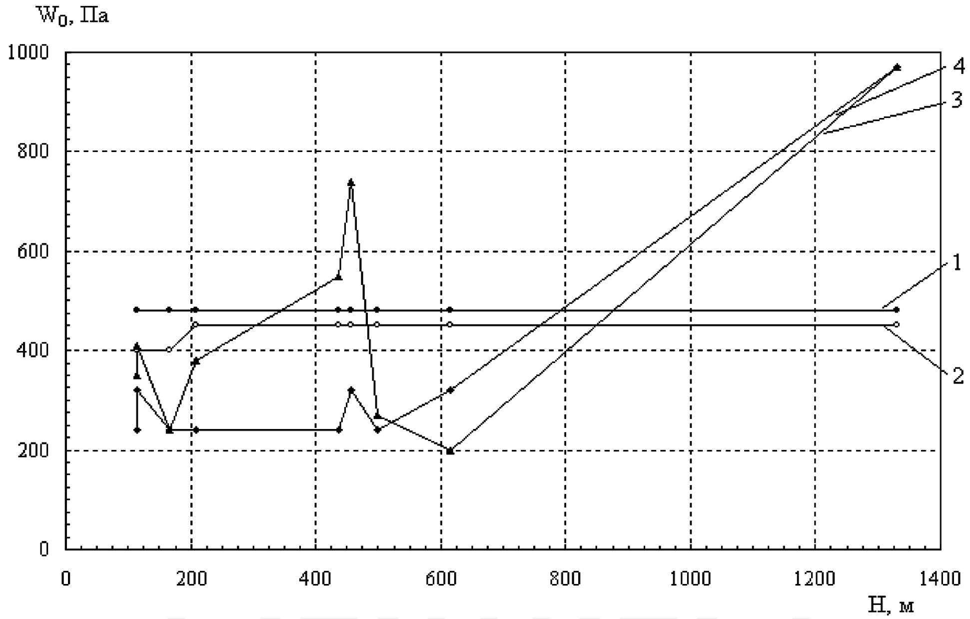

Fig. 2. Change of average compound of maximum wind pressure, W_o, due to [4] and [5] and data of the observations made from 1955 to 2005 at 9 meteorological stations: 1 – due to [5]; 2 – due to [4]; 3 – due to the observations at the meteorological stations made from 1955 to 2005 (summer); 4 – due to the observations at the meteorological stations made from 1955 to 2005 (winter)

The characteristic values of wind pressure, W_o, standardised by [4] for the lowlands of the Transcarpathian region comprises 400 Pa (first region), for mountainous regions 450 Pa (second region). In comparison to the received statistical data at the 9 meteorological stations of Transcarpathian region according to the observations made from 1955 to 2005 in July:

- for 5 meteorological stations, the actual values of maximum wind pressure W_o are raised too high within the limits of 12.5% to 55.6%;
- for 4 meteorological stations, the W_o values are set too low within the limits of 2.5% to 115%;

  in January:
- for 8 meteorological stations, the actual values of W_o are set too high within the limits of 20% to 46.7%;
- for meteorological station Plai, the actual values of W_o are set too low up to 115%.

4. Conclusions

1. The geographical altitude coefficient C_{alt} in the Transcarpathian region calculated according to [4] is not always correlated with the actual values received on the basis of investigations of the data of meteorological observations made from 1955 to 2005 at 9 meteorological stations.

2. The value of the coefficient C_{alt} given in [4] correlates with the value received according to the data of meteorological observations in January at 5 meteorological stations; for 3 meteorological stations, it is set too low; for meteorological station Plai, it is less than standard for 0.04; and in comparison with the summer period at 3 weather stations, it is higher than 1.0.
3. Using the method explained in [1, 2], according to 23 directions and altitude wind coefficients as well as data of meteorological observations made from 1955 to 2005, the geographical altitude coefficients for determination of wind loads in July and January for each residential area, peak and mountain pass for the Transcarpathian region of the Ukrainian Carpathians were calculated.
4. For precise determination of wind loads in mountainous regions, it is necessary to use data from many years of observations of wind speed at the weather stations of that particular region.

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