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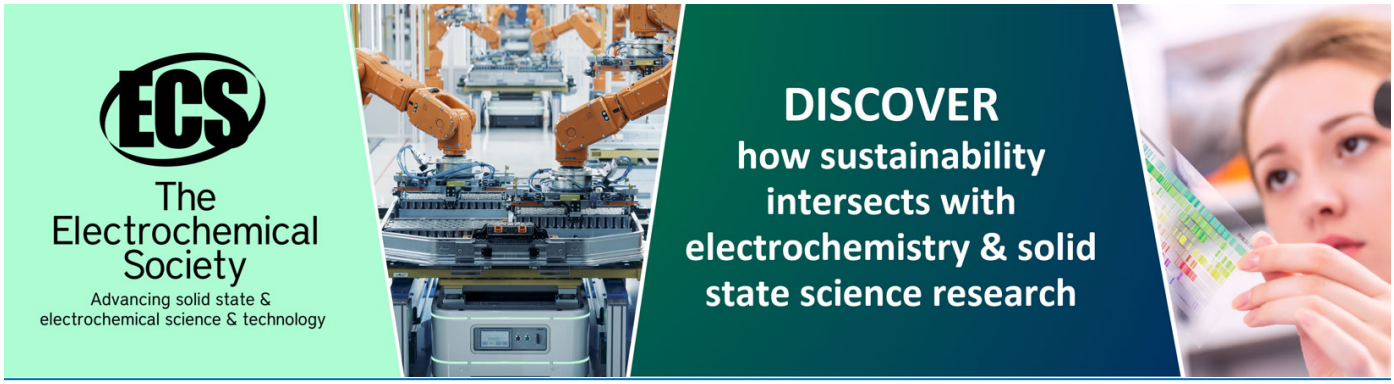

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Calculation Method of Maximum Snow Load in Depressions Located on the Territory of Transcarpathian Region According to the Simplified Formulae

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Abstract. The snow load in depressions has been actually studied partially according to the basic data of the snow cover in the III climatic zone of the Building Code of Ukraine, later on – according to the observed precipitation at meteorological observing stations, and over the last years – according to the observations at the meteorological observing stations. There have been used in this paper the observation data within the period from 1948 to 2015 with maximum snow cover depths and snow density in the depressions at 9 meteorological observing stations of Transcarpathian region (Ukraine) with the establishment of the simplified formulae of the average snow loads for the depression contour heights. It is enough to have the height of the point above the Baltic sea level to define maximum snow parameters in depressions: snow cover depth, snow density, snow load on the horizontal surface.

1. Introduction

The snow cover has a significant impact on the formation of the climate in winter as long as it has a high reflecting and radiation capacity. It sharply decreases the radiation balance, promotes cooling of the adjoining air layers and the formation of a firm anticyclone over the substantial part of the territory of the firm land. The snow, lying too long in large quantities in depressions (basins) and close to various obstacles, levels and smooths the bottoming surface, due to which its roughness decreases and wind speed increases. As a result of snow winnowing and transfer with a wind the appearance of the snow cover changes a lot, especially in the regions where the strong wind and rugged terrains predominate [1-3, 9]. The snow load in depressions has been actually studied partially according to the basic data of the snow cover in the III climatic zone [7, 8], later on – according to the observed precipitation at meteorological observing stations, and over the last years – according to the observations within the period from 1948 to 2015 at 9 meteorological observing stations of Transcarpathian region [5, 6, 13-16].

According to the snow parameters, Ukrainian Carpathians may be considered an independent region of Ukraine, where snow accumulations have been caused by vertical zonation and direction of the hills exposure [10, 12, 13].

Transcarpathian lowlands should be referred to a special region, which according to the climatic parameters is much different from the mountainous regions, especially according to the snow parameters [4, 5, 6, 13].

The goal and mission of the studies involve the establishment of the simplified formulae to define maximum snow parameters in depressions based on the given depression contour heights of Transcarpathian region above Baltic sea level.

2. The snow load study method

To calculate snow parameters in depressions there have been applied the altitude coefficients and 6 directions for maximum snow cover depths and 8 directions for maximum snow densities. The directions (Figure 1) have been drawn between the meteorological observing stations with the corresponding heights above the Baltic sea level [11]: Berehovo – 113m – Plai – 1330m; Uzhhorod – 114,6m – Plai – 1330m; Velykyi Bereznyi – 209m – Plai – 1330m; Rakhiv – 438m – Plai – 1330m; Mizhhiria – 456m – Plai – 1330m; Nyzhni Vorota – 500m – Plai – 1330m; Nyzhnii Studenyi – 615m – Plai – 1330m, besides there were used the depression contour heights of Transcarpathian region at 100m interval within the limits of 100m: (Chop) – 2061m (mount Hoverla). The basic data of snow parameters: maximum snow cover depths in depressions, maximum snow densities according to the observations made within the period from 1948 to 2015 at 9 meteorological observing stations of Transcarpathian region are presented in Table 1.

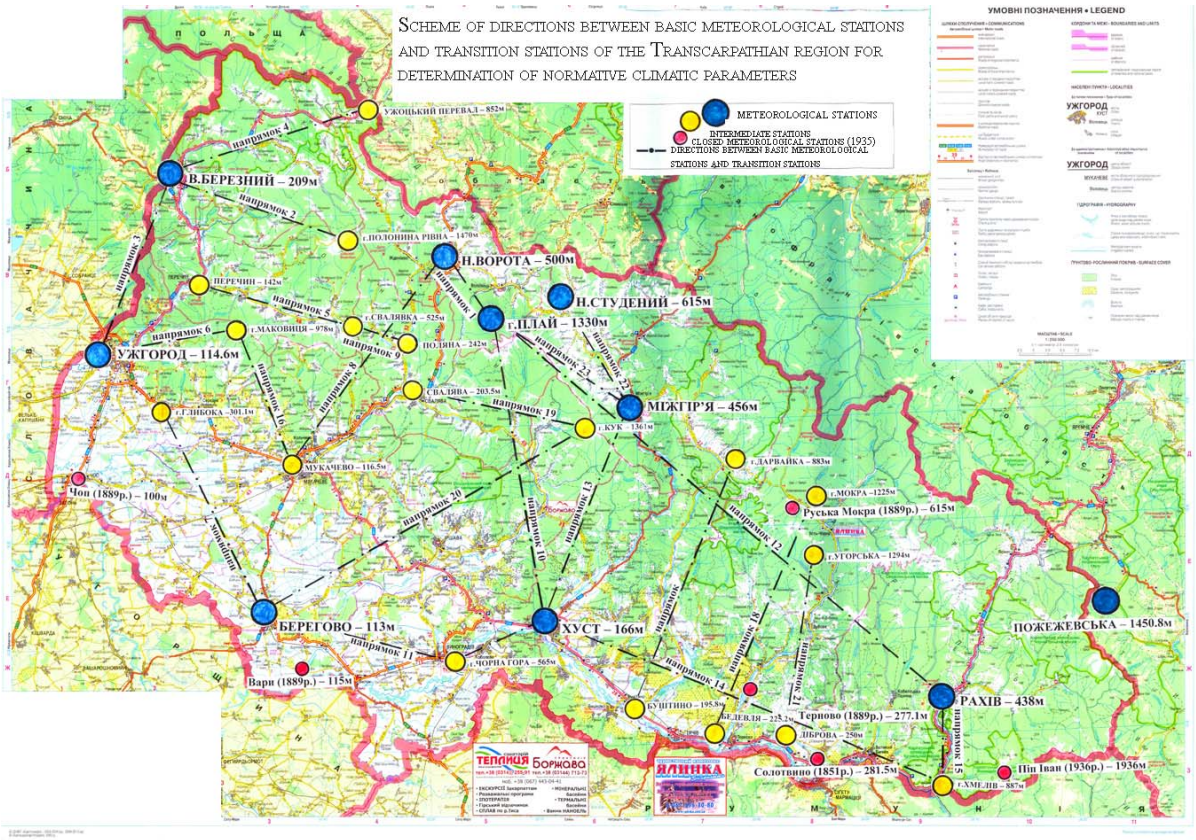

Figure 1. Direction chart between the basic meteorological observing stations and transitional stations of Transcarpathian region for the establishment of the specified climatic parameters

Table 1. Maximum snow cover depths and snow densities in depressions for 9 meteorological observing stations of Transcarpathian region

Name of the meteorological observing station	Altitude above the Baltic sea level, m	Maximum snow cover depth in depressions, m	Maximum snow density in depressions, kg/m^3
Berehovo	113	0,60	138
Uzhhorod	114,6	0,65	138
Khust	166	1,00	171
Velykyi Bereznyi	209	0,90	166
Rakhiv	438	1,85	218
Mizhhiria	456	2,50	295
Nyzhni Vorota	500	1,80	255
Nyzhnii Studenyi	615	2,30	331
Plai	1330	2,50	340

Maximum snow parameters in depressions by the altitude coefficients were calculated according to the following formulae:

$$P_{X\max,dep.} = P_{1\max,dep.} + K_{\max,dep.}(H_X - H_1), \quad (1)$$

$$K_{\max dep.} = \frac{P_{2\max,dep.} - P_{1\max,dep.}}{H_2 - H_1}, \quad (2)$$

where: $P_{1\ max,\ dep.}$, $P_{2\ max,dep.}$, $P_{X\ max,dep.}$ – maximum indices (height and density) of the snow cover at the stations X, 1, 2 (at depression contour heights), m, kg/m^3;

$K_{\ max,\ dep.}$ – altitude coefficient of maximum (heights, densities) of the snow cover, m/m, kg/m^3;

H_X, H_X, H_2, – heights of stations X, 1, 2, (depression contour heights) above the Baltic sea level, m.

Maximum snow load $\rho_{max,\ dep.}$, Pa, was calculated according to the following formula:

$$\rho_{\max,X,dep.} = 9.8\rho_{\max,X} \cdot h_{\max X,dep.}, \quad (3)$$

where: $\rho_{max.,X}$ – maximum snow density at the station X, kg/m^3;

$h_{max.X,\ dep.}$ – maximum snow cover depth at the station X, m;

9.8 – transitional coefficient from kg/cu.m into Pa.

Calculation results of the snow parameters in depressions are presented in Tables 3a, 3b.

3. Own theoretical studies

In the previous studies for the calculation of the maximum snow parameters in depressions: snow cover depths, snow densities, snow loads [1-25] there was used the altitude coefficient method and 23 directions (figure 1) among the meteorological observing stations and transitional stations and formulae (1) – (3).

To establish the simplified formulae of maximum snow parameters in depressions: snow density, kg/m^3, snow cover depth, m, snow load on the horizontal surface, Pa, in tables 2a, 2b, 3a, 3b end 3c there are additionally calculated the sum of differences of these parameters and the analogous sum of heights between the heights of the adjoining horizontals and the interval of their application is taken by their unambiguity. In each interval there is calculated an additional coefficient of the simplified formula:

$$K_{sn.p.,int} = \frac{\Sigma\Delta R_{int}}{\Sigma\Delta H_{int}}, \quad (4)$$

where: $K_{sn.p.int}$ – an additional coefficient of the simplified formula for the unambiguous interval of the horizontal heights;

$\sum \Delta R_{int}$ – a sum of the unambiguous differences of maximum snow parameters in depressions of the analogous heights interval;

$\sum \Delta H_{int}$ – a sum of the horizontal heights difference in the unambiguous differences interval of maximum snow parameters.

The simplified formulae of maximum snow parameters in depressions are presented in table 2.

Table 2a. Summary table of the simplified formulae for the calculation of the maximum snow parameters in depressions

Horizontals heights on the topographic maps, m	Simplified formulae of maximum snow cover depth in depressions	Horizontals heights on the topographic maps, m	Simplified formulae of maximum snow density in depressions
100 – 300	$h_{\max sn.X,dep.} = 0{,}235 + 0{,}00348 H_X$	100 – 300	$\rho_{\max\ sn.X,dep.} = 110{,}13 + 0{,}2558\ H_X$
300 – 600	$h_{\max sn.X,dep.} = 0{,}354 + 0{,}00289 H_X$	300 – 500	$\rho_{\max\ sn.X,dep.} = 129{,}67 + 0{,}1581\ H_X$
600 – 2061	$h_{\max sn.X,dep.} = 1{,}449 + 0{,}00079 H_X$	500 – 600	$\rho_{\max sn.X,dep.} = 42{,}47 + 0{,}3761 H_X$
		600 – 700	$\rho_{\max\ sn.X,dep.} = 97{,}85 + 0{,}2408\ H_X$
		700 – 2061	$\rho_{\max sn.X,dep.} = 184{,}429 + 0{,}11697 H_X$

Table 2b. Summary table of the simplified formulae for the calculation of the maximum snow parameters in depressions

Horizontals heights on the topographic maps, m	Simplified formulae of maximum snow load on the horizontal surface in depressions
100 – 300	$P_{sn.dep.} = (0{,}235 + 0{,}00348\ H_X) \cdot (110{,}13 + 0{,}2558\ H_X) \cdot 9{,}8$
300 – 400	$P_{sn.dep.} = (0{,}354 + 0{,}00289\ H_X) \cdot (129{,}67 + 0{,}1581 H_X) \cdot 9{,}8$
400 – 600	$P_{sn.dep.} = (0{,}354 + 0{,}00289\ H_X) \cdot (42{,}47 + 0{,}376\ H_X) \cdot 9{,}8$
600 – 2061	$P_{sn.dep.} = (1{,}449 + 0{,}00079\ H_X) \cdot (184{,}429 + 0{,}11697\ H_X) \cdot 9{,}8$

The formula for the calculation of additional snow parameter value inside the interval of their unambiguous differences between the horizontals is as follows:

$$P_{add.,int} = P_{X,int} - K_{sn.p.,add.int}, \quad (5)$$

where: $P_{add.X,\ int}$ – an additional snow parameter of the simplified formula in the middle of the interval of the accepted horizontal heights;

$P_{X,\ int}$ – snow parameter in the middle of the sum interval.

The general simplified formula of maximum snow parameters within the limits of the horizontal heights interval activity is as follows:

$$P_{Xint} = \left(P_{X_1 int} - K_{sn.p.,add.int} \cdot H_{X_1}\right) + K_{sn.p.,add.int} \cdot H_X, \quad (6)$$

Where $P_{X,int.}$ – maximum snow parameter at the height H_X within the limits of the horizontal heights interval activity.

4. Studies results and their analysis

In the dependencies (figures 2, 3, 4) there have been reflected the received results of the studies for the change of maximum snow parameters in depressions from the placement of the heights of the transitional stations (horizontal heights on the topographic maps) above the Baltic sea level.

The analysis of calculation results of maximum snow loads in depressions according to the altitude coefficients (numerator) and according to the simplified formulae (denominator) is presented in tables 3.

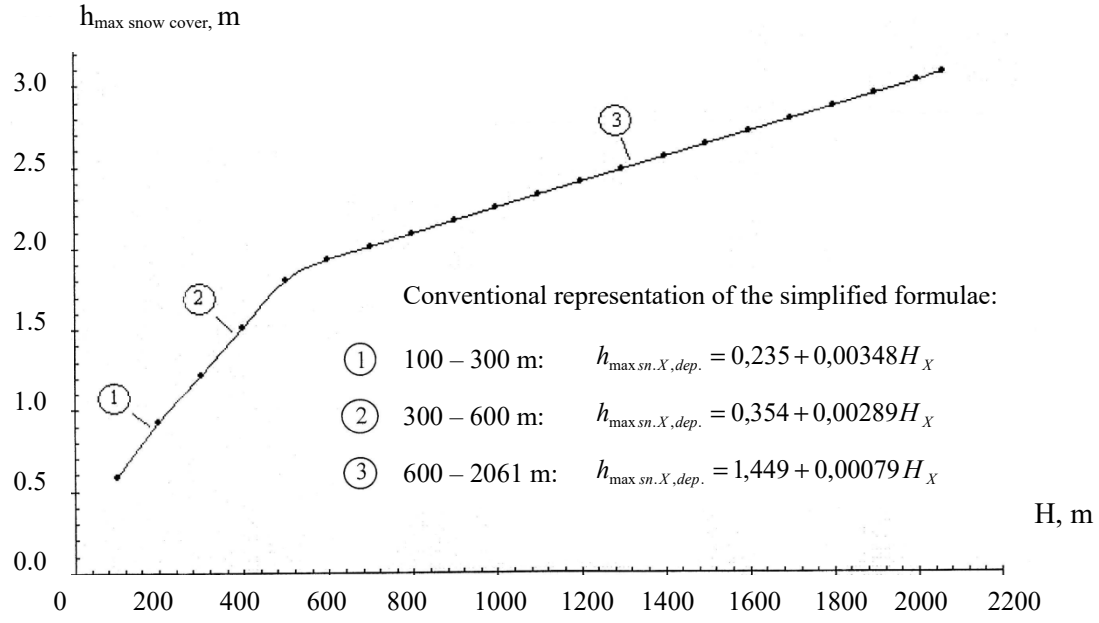

Figure 2. The dependence of the maximum snow cover depth in depressions on the station placement heights (horizontals heights on the topographic maps) above the Baltic sea level for the territory of Transcarpathian region

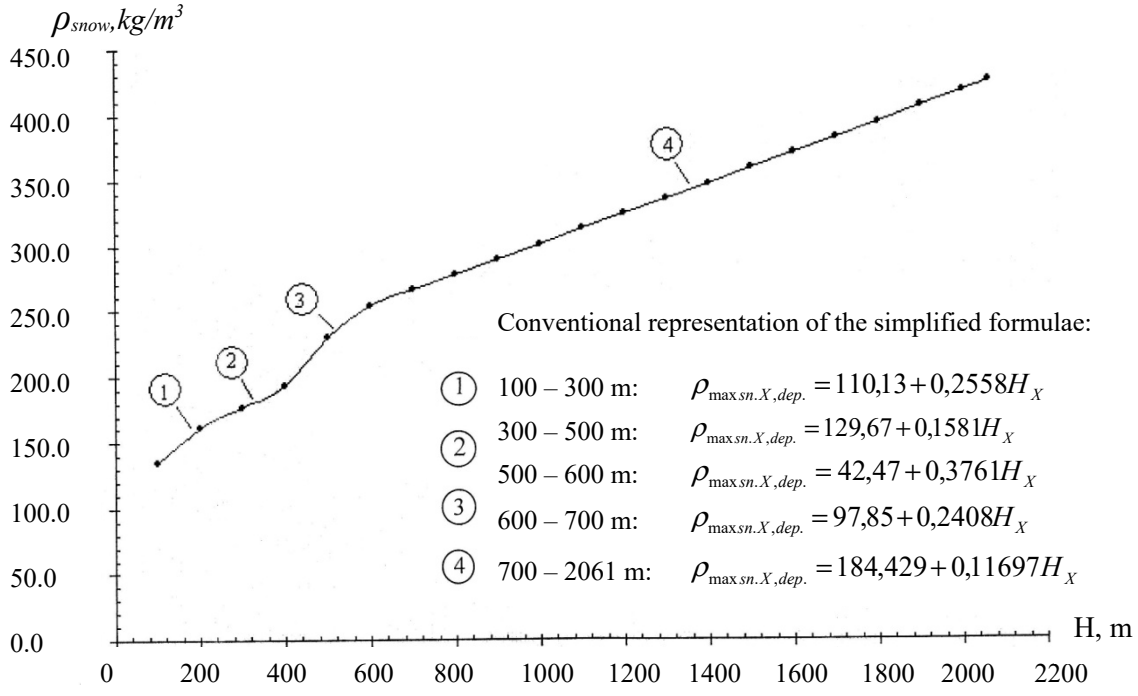

Figure 3. The dependence of the change of the snow cover maximum densities in depressions on the station placement heights (horizontals heights on the topographic maps) for the territory of Transcarpathian region

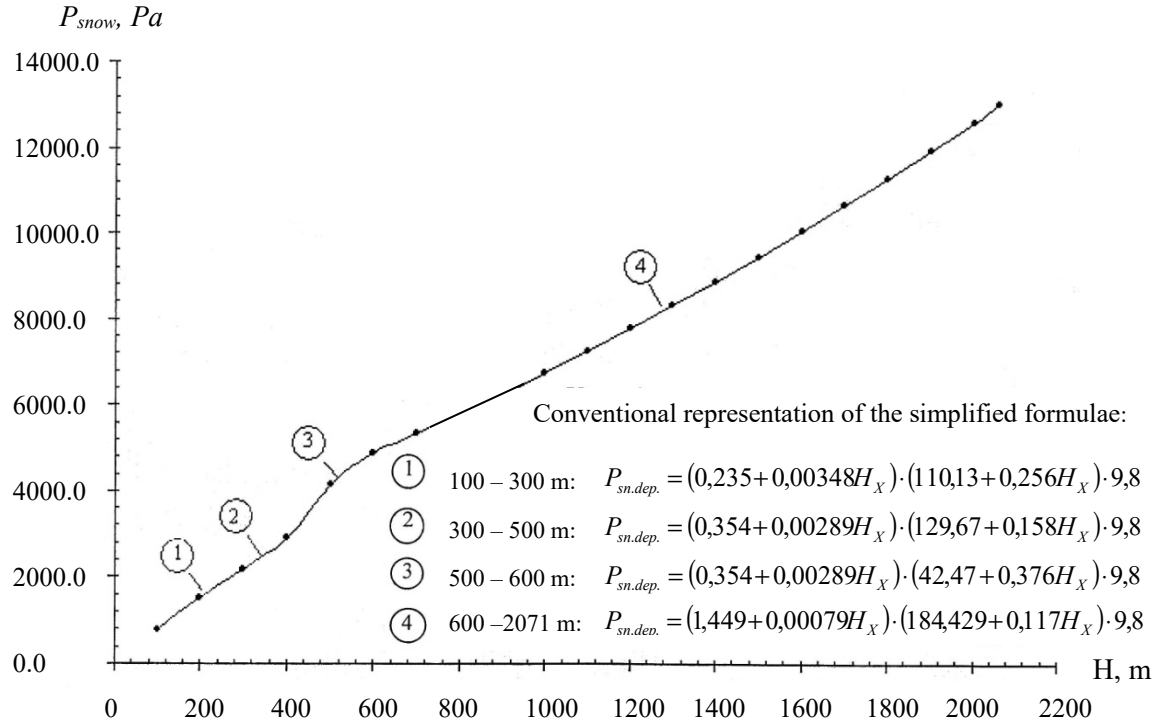

Figure 4. The dependence of change of maximum snow load in depressions on the station placement heights (horizontals heights on the topographic maps) for the territory of Transcarpathian region

Table 3a Calculation results of maximum snow loads on the horizontal surface in depressions with the establishment of the simplified formulae

Name of components of maximum snow load in depressions	Horizontals heights on the topographic maps, m						
	100	200	300	400	500	600	700
Maximum snow cover depth, m, *	0,583 / 0,583	0,931 / 0,931	1,220 / 1,221	1,510 / 1,510	1,799 / 1,799	1,926 / 1,926	2,004 / 2,002
Maximum snow density, kg/m^3, *	135,71 / 135,71	161,29 / 161,29	177,10 / 177,10	192,91 / 192,91	230,52 / 230,52	254,60 / 254,60	266,41 / 266,31
Maximum snow load, kg/m^2, *	79,11 / 79,11	150,16 / 150,16	216,06 / 216,06	291,29 / 291,29	414,70 / 414,70	490,35 / 490,35	533,88 / 533,14
Maximum snow load, Pa, *	775,27 / 775,27	1471,56 / 1471,56	2117,38 / 2117,38	2854,64 / 2854,64	4064,06 / 4064,06	4805,43 / 4805,43	5232,02 / 5224,77
Difference of calculations: Pa – numerator; % – denominator	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0	− 7,25 / − 0,12

*calculated: a) according to the altitude coefficients – numerator; b) according to the simplified formulae – denominator

Table 3b Calculation results of maximum snow loads on the horizontal surface in depressions with the establishment of the simplified formulae

Name of components of maximum snow load in depressions	Horizontals heights on the topographic maps, m						
	800	900	1000	1100	1200	1300	1400
Maximum snow cover depth, m, *	2,083 / 2,083	2,162 / 2,160	2,240 / 2,239	2,319 / 2,318	2,397 / 2,397	2,476 / 2,476	2,554 / 2,555
Maximum snow density, kg/m^3, *	277,99 / 278,01	289,69 / 289,70	301,39 / 301,39	313,08 / 313,09	324,78 / 324,79	336,48 / 336,49	348,18 / 348,18
Maximum snow load, kg/m^2, *	579,05 / 578,52	626,30 / 625,75	675,11 / 674,81	726,03 / 725,74	778,49 / 778,52	833,12 / 833,14	889,25 / 889,59
Maximum snow load, Pa, *	5674,69 / 5669,49	6135,87 / 6132,35	6616,07 / 6613,13	7115,09 / 7112,25	7629,20 / 7629,49	8164,5 / 8164,7	8714,65 / 8717,98
Difference of calculations: Pa – numerator; % – denominator	−5,2 / −0,09	−3,52 / −0,05	−2,94 / −0,04	−2,84 / −0,04	+0,59 / +0,007	+0,2 / +0,012	+3,33 / +0,03

*calculated: a) according to the altitude coefficients – numerator; b) according to the simplified formulae – denominator

Table 3c Calculation results of maximum snow loads on the horizontal surface in depressions with the establishment of the simplified formulae

Name of components of maximum snow load in depressions	Horizontals heights on the topographic maps, m						
	1500	1600	1700	1800	1900	2000	2061
Maximum snow cover depth, m, *	2,633 / 2,634	2,711 / 2,713	2,790 / 2,792	2,869 / 2,871	2,947 / 2,950	3,026 / 3,029	3,074 / 3,077
Maximum snow density, kg/m^3, *	359,87 / 359,88	371,57 / 371,58	383,27 / 383,27	394,97 / 394,97	406,66 / 406,67	418,36 / 418,36	425,50 / 425,50
Maximum snow load, kg/m^2, *	947,53 / 947,92	1007,32 / 1008,09	1069,32 / 1070,08	1133,16 / 1133,95	1198,42 / 1199,67	1265,95 / 1267,21	1307,98 / 1309,26
Maximum snow load, Pa, *	9285,79 / 9289,61	9871,73 / 9879,28	10479,33 / 10486,78	11104,96 / 11112,71	11744,51 / 11756,76	12406,31 / 12418,65	12818,20 / 12830,74
Difference of calculations: Pa – numerator; % – denominator	+3,82 / +0,03	+7,55 / +0,07	+7,45 / +0,07	+7,75 / +0,07	+12,25 / +0,10	+12,34 / +0,1	+12,54 / +0,1

*calculated: a) according to the altitude coefficients – numerator; b) according to the simplified formulae – denominator

5. Conclusions

1. On the basis of the undertaken studies, there have been suggested for the first time the simplified formulae for the defining of maximum snow parameters in depressions for the territory of Transcarpathian region (Ukraine).
2. It is enough to have the height of the point above the Baltic sea level to define maximum snow parameters in depressions: snow cover depth, snow density, snow load on the horizontal surface. The divergence of calculations made according to the simplified formulae and calculation of these parameters according to the altitude coefficients makes from 0 to 1,0%.
3. Maximum snow load in depressions is applied for the calculation of the complex shape roof design.

4. The received parameters of the snow load are used for skiing lodges design on mountainous territories and for calculation of water reserve from snow melting in case of freshets.
5. It is necessary to use the suggested snow specified parameters in depressions while correcting the state building norms

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References
[1] V. N. Babichenko, "Climate of Uzhgorod", Leningrad, 190p. 1991. (in Russia)
[2] M. I. Budyko, "Climate in the past and future", Leningrad, 351p. 1980 (in Russia)
[3] I. E.Buchinskiy, "Climate of Ukraine", Leningrad: Gidrometeoizdat, 130. 1960 (in Ukraine)
[4] M. I. Guk, I. K Polovko., G. F. Prihotko, "Climate of URSR" – Kiev: Soviet school, 72p.,1958. (in Ukraine).
[5] Ya. S. Huk, "Determination of recommended regulatory parameters of pressure for settlements, separate peaks and passes of the Transcarpathian region", Scientific Herald Uzh NU. Seriya: Fizyka, Uzhgorod, Vol. 19, pp.206 – 208. 2006 (in Ukraine)
[6] Ya. S. Huk, „Method of determining the heights of the horizons on topographic maps of the Transcarpathian region corresponding to maximum winter and summer wind pressures", Collector of scientific works. Series: Sectoral engineering, construction, Poltava, Vol. 2 (44), pp.42 – 51. 2015 (in Ukraine)
[7] DSTU NB V.1.1-21:2010. Protection against dangerous geological processes, harmful operational influences, fires. Construction climatologists", Ukraine, 55p., 2010. (in Ukraine)
[8] DBN V.1.2-2:2006, Sistema zabezpechennya nadiynosti ta bezpeki budivelnih ob'ektiv. Navantazhennya i vplivi. Normi proektuvannya. – Kyiv, Ukraine, 75p. , 2006 (in Ukraine)
[9] EN Eurocode 1: Actions on Structures. Part.1.3 Snow Loads, GEN Central Secretariat, Brussels. pp.10-11, 2002.
[10] GSN 730035/ Zatizeni stavebnich Konstrukci vydavatelstvi hradu pro normalizaci a mereni, Praha, P.21-23, 1986.
[11] Zakarpatska obl. Zagalnogeografichna karta (1:250 000), Kyjiv: AGP, 2006. (in Ukraine)
[12] S. F. Pichugin, "Probabilistic Analysis on Wind Load and Reliability of Structures", *Proceedings of the 2 EACWE*. Vol. 2, Genova, Italy, pp.1883–1890, 1997.
[13] R. I. Kinash, O.M. Burnayev, "Snow load in the Ukraine" Lviv: Directory, 140p., 2000. (in Ukraine)
[14] R. I. Kinash, Ya. S. Huk, "Technique of definition of parameters building of climatology for settlements, tops and passes of the Transcarpathian region" *Proceedings Problems of the Technical Meteorology* (22 – 26 may, 2006), Lviv, Ukraine, pp.50 – 56, 2006. (in Ukraine)
[15] R. Kinasz, Y. Huk, "Application of factor geographically heights for determining snow loads in the mountainous district Transcarpathian region" *Metal constructions*, Makeevka, vol. 18, no 4, pp. 219–226, 2012. (in Ukraine)
[16] R. Kinasz, Y. Huk, "Method of determining characteristic values of average and maximum wind pressure from the Carpathians zoning Trans Carpathian Region" IOP *Conference Series: Materials Science and Engineering*, vol. 245 art. no. 022094, pp. 1–9, 2017.