4. Snow load

This chapter was prepared basically by using the data contained in the „snow" standard and several s-cientific positions (PN-EN 1991-1-3:2005, Flaga A., Kimbar G. (2007), Sobolewski A., Żurański J.(2010), Żurański J., Gaczek M. (2011)).

4.1. Introduction

Ice crystals are created in the atmosphere as a result of weather factors. Their size is dependent on the humidity level and temperature. In different conditions, diverse types of crystals are created such as, dendrites, plates and needles. Over 80 various forms of snow crystals are distinguished. Their size oscillates from 0,1mm to 4mm. As a result of mutual collisions, gluing of crystals can occur, which leads to the creation of more complex forms of crystals.

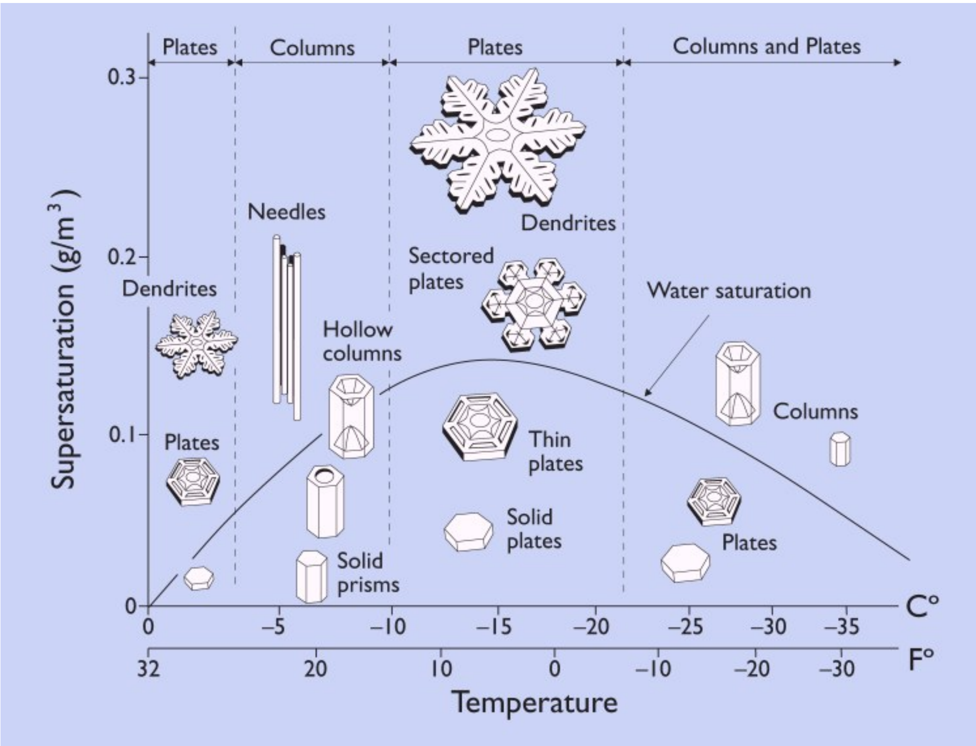

Fig. 4.1. Different form of snow crystals

Ice particles, which are under the influence of gravity force and aerodynamic forces, move in the direction of globe. In a larger scale, the motion of large number of ice particles can be described as dispersion motion, i.e.: certain volume characterized by averaged properties of particles motion included into its composition. One of the main properties is the concentration of dispersion. At high altitude, conditions which dispersion is subjected to can be treated as homogeneous. The situation is diverse in the case of approximating the surface of globe where the air flow is influenced by different types of obstacles. Then, there occurs the difference in ice particle concentration, which especially takes place just above the roof surface of buildings. Acting wind and existing obstacles lead to the increased concentration, which has an effect in a thicker layer of snow cover on the external side of roof, and less concentration on the windward side leads to slower growth of snow cover. It means uneven disposition of snow on the roof surface. During snow accumulation on the roof, at wind action, humidity variable and air temperature, there occur the changes of physical properties. The consequence of this is the change of snow structure porosity. Simultaneously, every new snowfall leads to the creation of new layer of snow of less porosity than already accumulated layers on the roof. At the same time, the weight of upper snow layers and wind action lead to snow concentration. The phenomena of sublimation and resublimation of snow crystals have also the impact on the increase of snow concentration. The effects of above mentioned factors cause stronger binding of ice particles in the cover. The rise of temperatures above 0°C causes melting of snow and water occurrence, and after the decrease of temperature, the appearence of ice. This situation can also occur when there is a heat transfer from the interior of a building. Bottom layers of snow in the cover are subjected to a density alteration. In general, it can be stated that bulk density of snow grows along with the time of cover accumulation.

Indicative values of average bulk density of snow on the ground are shown in the below table:

Table 4.1. Average bulk density of snow on the ground

Type of snow	Bulk density [kN/m^3]
Fresh	1.0
Settled (several hours or days after snowfalls)	2.0
Old (several weeks or months after snowfalls)	2.5 – 3.5
Wet	4.0

Layers characterized by diverse physical properties are less or more subjected to redistribution. The thickness of snow cover on roofs is also dependent on other factors such as, angle of inclination and roof shape. Appropriate angle of roof inclination causes snow sliding under the influence of its bulk density. Human impact is not without significance since accumulated snow can be removed mechnically. The phenomena discussed above are presented in the below graph (Fig. 4.2).

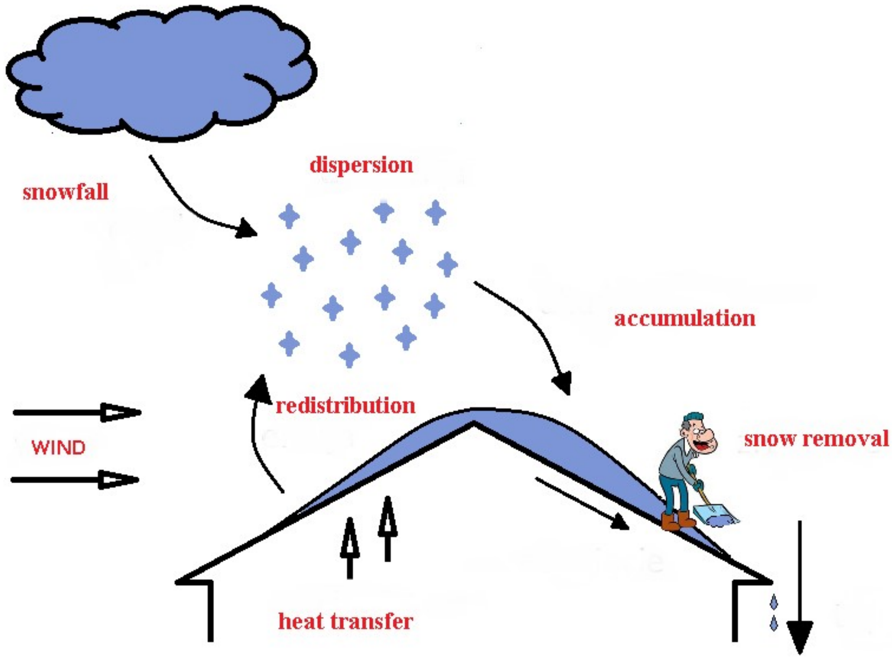

Fig. 4.2. Phenomena exerting an impact on the distribution of snow cover.

4.2. Snow load according to PN-EN 1991-1-3: 2005

The weight of snow cover on the ground is a basic value considered in snow load. This quantity is treated as a random variable. Moreover, this value is based on the readings of thickness and weight of snow lying on the ground and it is collected by weather stations located in the country which the standard is referred to. This quantity is called as characteristic value of snow load on the ground S_k and it is defined at quantile level of 0,98 for the distribution of maximum annual values and recovery period – 50 years. To determine this value, empirical distribution of snow load on ground from many years was available which was approximated by the probability of Gumbel extreme value distribution.

Other coefficients such as, considering roof shape, exposure and thermal coefficients were determined on the basis of research data or as average values available from measuring data.

According to the standard, roof properties and other factors causing different distribution of snow can include:

a) Roof shape,
b) Its thermal properties,
c) Surface roughness,
d) Amount of heat produced under the roof,
e) Proximity of neighboring buildings,
f) Surrounding area,
g) Local climatic conditions, in particular winds, temperature differences and the likelihood of precipitation (rain, snow).

Snow load of roof is expressed by the following formulas:

- In a permanent and temporary calculation situation

$$s = \mu C_e C_t s_k \tag{1.1}$$

- In an exceptional situation in which snow load is treated as an exceptional effect

$$s = \mu_i C_e C_t s_{Ad} \tag{1.2}$$

- In an exceptional calculation situation in which exceptional snowdrifts are treated as an exceptional effect and annex B is applied

$$s = \mu_i s_s \tag{1.3}$$

Notations occurring in formulas:

μ_i - coefficient of roof shape;

C_e - exposure coefficient;

C_t - thermal coefficient;

s_k - characteristic value of snow load on ground;

s_{Ad} - calculation value of exceptional snow load on ground.

Value s_{Ad} is calculated by the product s_k and exceptional snow load C_{esI} whose recommended value is 2.

Coefficient C_e considers a general wind impact on the size of snow cover. The standard recommends three values of this coefficient, corresponding to different terrain conditions:

- C_e=0.8 – building is located in the area exposed to wind action (plain areas without obstacles, open on all sides, without covers or with small covers formed by terrain, higher buildings or trees),
- C_e =1.0 – building is located in the normal area (areas in which there is no significant transfer of snow by wind to buildings due to the shape of terrain, other buildings or trees),
- C_e =1.2 – building is located in the area sheltered from wind (areas in which a building in question is much lower than surrounding area or surrounded by tall trees or higher buildings).

Coefficient C_t of value lower than 1.0 takes into account heat transfer by a roof, which results in the reduction of snow load (in particular roofs covered by glass). In other cases, the value equal to 1.0. is assumed.

Coefficient μ_i is the main coefficient between the snow load of ground and load of roof. Different ways of loads and values of coefficients μ_i of several roof shapes are compiled in the standard: mono-pitch roof, gable roof, multi hipped roof, barrel-vault roof, as well as roofs adhering to higher buildings, roofs with obstacles and ridges. Moreover, the approach to calculate snow cornices on the roof edge and snow load of snow barriers is discussed.

In the standard there are two basic systems of loads: even and uneven snow loads of roofs. In the case of mono-pitch roof, gable roof and multi hipped roof, the coefficient of roof shape μ_i depends on the value of inclination angle of roof slope, which can be read from Fig. 4.3. or can be calculated from the dependencies shown in Tab. 2. Coefficients μ_i have the values different from zero in the angle range of 0° - 60°.

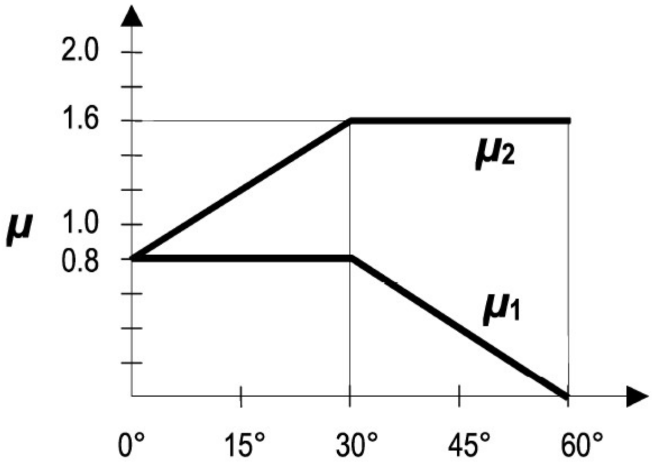

Fig. 4.3. Coefficients of roof shape

Table 4.2. Coefficients of roof shape

Angle of roof inclination α	$0° \leq \alpha \leq 30°$	$30° < \alpha < 60°$	$\alpha \geq 60°$
μ_1	0.8	0.8(60 - α)/30	0.0
μ_2	0.8 + 0.8α/30	1.6	-

In the case of mono-pitch roofs (Fig. 4.4), just one case of even snow load occurs and it refers to the roof value μ_1 = 0.8, in the range of inclination angles of roof slope 0° - 30° and of value μ_1 = 0.8 – 0, in angle range 30° - 60°.

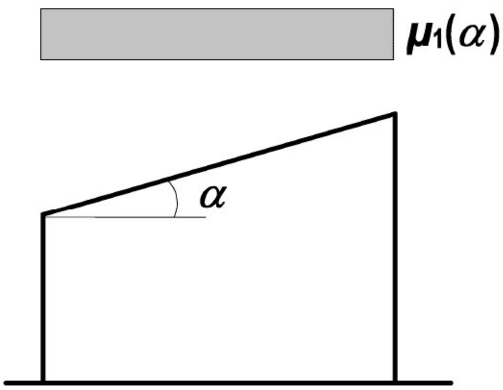

Fig. 4.4. Coefficients of mono-pitch roof shape

In the case of gable roofs (Fig. 4.5), there occur three cases of snow load of roofs. If roof slopes are inclined at the same angle, the first load is even, of maximum value μ_1 =0.8. Cases two and three are the examples of uneven snow load, of maximum value μ_1 =0.8 on one roof slope and half value μ_1 on the other.

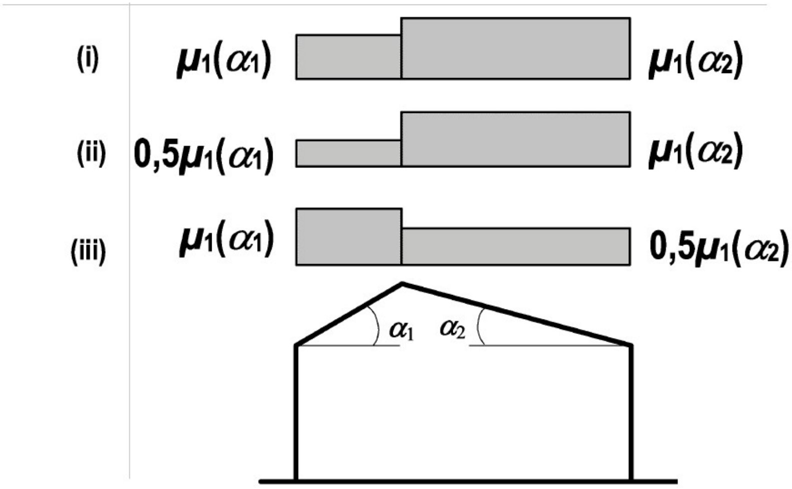

Fig. 4.5. Coefficients of gable roof shape

In the case of multi hipped roof (Fig. 4.6), there are two cases of loads. If the roof slope is inclined at 30°, then in the first case of load, there appears one value of coefficient μ_1 on all roof slopes, and in the second case of load, the coefficient μ_2=1.6 is assumed between internal roof slopes. The constant coefficient equal to 0.8. is assumed for the rest of roof slopes.

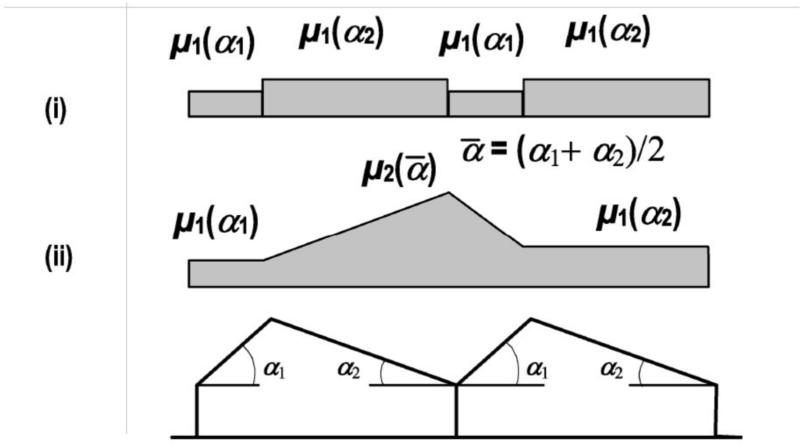

Fig. 4.6. Coefficients of multi hipped roof shape

In barrel-vault roofs, there occur the two cases of loads (Fig. 4.7), the first one is even, of the shape coefficient value equal to 0.8, and uneven one, of maximum value μ_3 on the one part, and of maximum value 0.5 μ_3 on the other part. Recommended values of barrel-vault roof shape coefficient of different rise-span ratio are presented in Fig. 4.8.

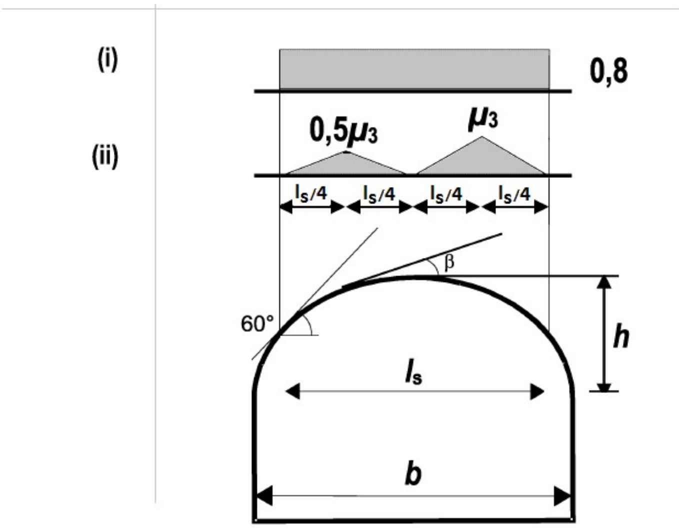

Fig. 4.7. Coefficients of barrel-vault roof shape

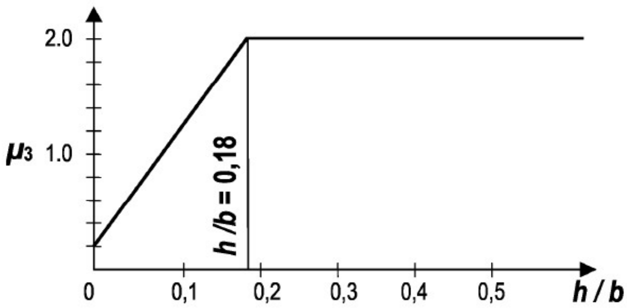

Fig. 4.8. Recommended barrel-vault roof shape coefficients of different rise-span ratio (for β ≤ 0)

In the case of close or adhering roofs to higher buildings (Fig. 4.9), the roof shape coefficient reaches constant value equal to 0.8 in the first case of load as well as a variable value related to the occurrence of a snowdrift of the length l_s in the second case. Two situations referring to the length of adhering roof b_2 are distinguished: the first when $b_2 > l_s$ and the second if $b_2 < l_s$. The first case considers the entire length, the second, partial length of snowdrift. The value μ_2 is defined as the sum of μ_s and μ_w.

The coefficient μ_s considers the effect of snow sliding down from higher roof and it equals 0, if $\alpha \leq 15°$. In the case when an angle $\alpha > 15°$, μ_s is determined as additional load which is 50% of total maximum snow load of higher roof slope, calculated acc. to point 5.3.3 of the standard.

The coefficient μ_w considers wind effect, its value is calculated acc. to the formula:

$$\mu_w = (b_1 + b_2)/2h \leq \gamma h / s_k \tag{1.4}$$

where:

γ - volume weight of snow bulk density which can be assumed as equal to 2kN/m^3.

The recommended value range μ_w is from 0.8 to 4.

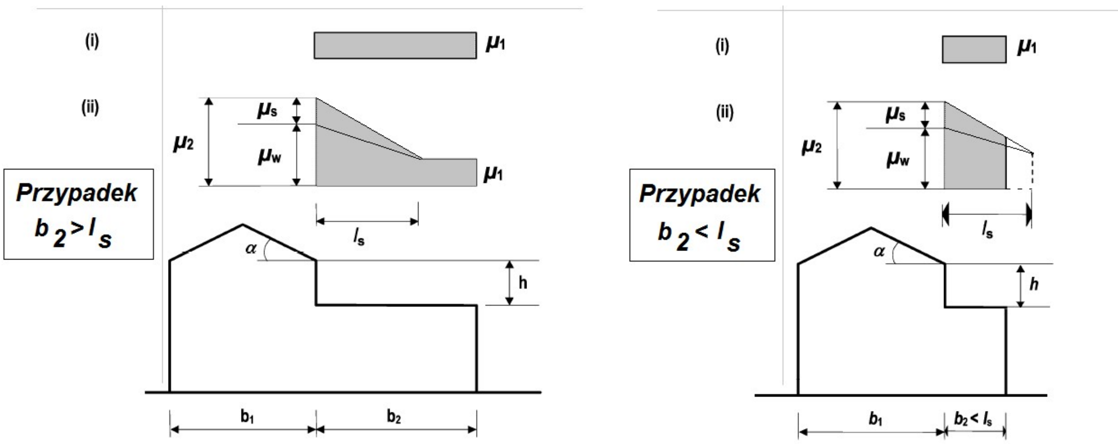

Fig. 4.9. Coefficients of shape for roofs adhering to higher buildings

Local loads in the case of snowdrift due to obstacles are decided on the basis of shape coefficient from Fig. 4.10. The value of roof shape coefficient μ_1 = 0.8 can reach the value from od 0.8 to 2. The length of snowdrift is $l_s = 2h$ and can reach values from 5m to 15m.

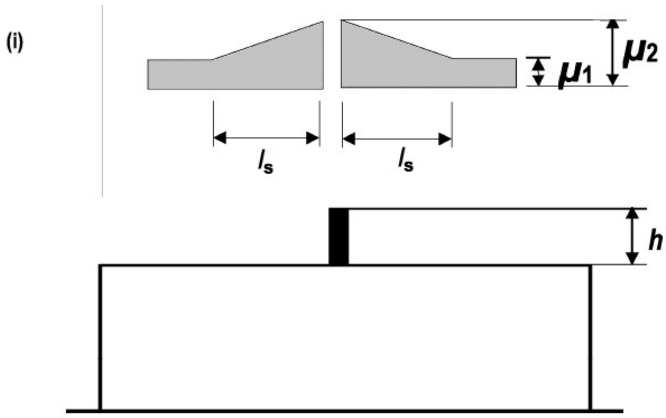

Fig. 4.10. Coefficient of roof shape in the case of snowdrift due to ridges and obstacles

Annex B of the standard shows the coefficients of roof shape for exceptional snowdrifts. Roof shape coefficients of multi hipped roof are here given (Fig. 4.11). Coefficient μ_1 is calculated as the least from three values: $2h/s_k$, $2b_3/(l_{s_1}+l_{s_2})$ and value 5.

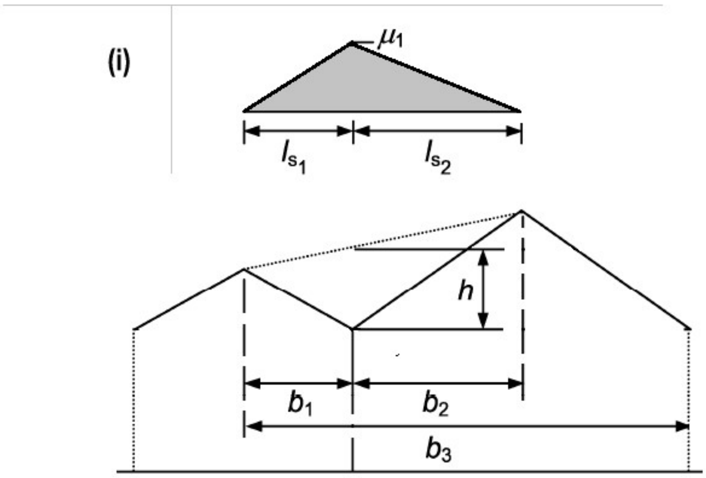

Fig. 4.11. Coefficient of roof shape and length of exceptional snowdrifts in the hollows of multi hipped roofs

In the country annex, the division of Poland into snow load zones of ground (Fig. 4.12), and characteristic values of snow loads of ground in Poland are compiled in Tab. 3, which were developed on the basis of snow load measurements on ground obtained from 115 meteorological stations of Institute of Meteorology and Water Management from the range of years: 1950-2000.

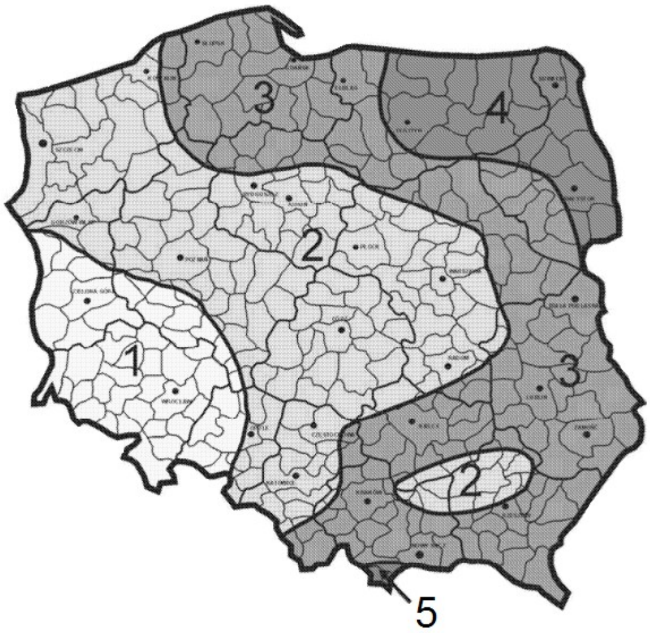

Fig. 4.12. The division of Poland into snow load zones of ground

Table 4.3. Characteristic values of snow loads of ground in Poland

Zone	s_k,
	[kN/m^2]
1	0.007A - 1.4; $s_k \geq 0.70$
2	0.9
3	0.006A - 0,6; $s_k \geq 1.2$
4	1.6
5	0.93exp(0.00134A); $s_k \geq 2.0$
Caution: A = Height above sea level	