International Standard

ISO 4355

Bases for design of structures — Determination of snow loads on roofs

Bases du calcul des constructions — Détermination de la charge de neige sur les toitures

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4355 was developed by Technical Committee ISO/TC 98, *Bases for design of structures*, and was circulated to the member bodies in November 1978.

It has been approved by the member bodies of the following countries :

Australia	Hungary	Poland
Austria	India	Portugal
Belgium	Ireland	South Africa, Rep. of
Canada	Israel	Spain
China	Italy	Sweden
Czechoslovakia	Japan	Turkey
Denmark	Korea, Rep. of	United Kingdom
Egypt, Arab Rep. of	Netherlands	USSR
France	New Zealand	Yugoslavia
Germany, F.R.	Norway	

The member body of the following country expressed disapproval of the document on technical grounds :

Switzerland

Contents

Bases for design of structures — Determination of snow loads on roofs

0 Introduction

The intensity and distribution of snow load on roofs may be described as functions of climate, topography, shape of building, roof surface material, heat flow through the roof and time. Since sufficient data describing these functions are not available, it is not possible at present to treat the problem by the theory of probability. As a consequence, for this International Standard, it has been decided to treat the problem in a semi-probabilistic way.

The characteristic snow load on a roof area, or any other area above ground which is subject to snow accumulation, is in this International Standard defined as the product of the characteristic snow load on the ground[1], s_o, specified for the region considered and the nominal shape coefficient, μ, applicable to the particular roof area considered. Other methods for estimating snow load on roofs will not be treated here.

In order to apply this International Standard, each country will have to establish maps and/or other information concerning the geographical distribution of ground snow load in that country. Procedures for a statistical treatment of meteorological data are described in annexes A and B.

The shape coefficients will depend on climate (especially duration of snow season), wind, local topography, geometry of the building and surrounding buildings, roof surface material, building insulation, etc. The snow can be redistributed as a result of wind action; melted water can flow into local areas and refreeze, and snow can slide or can be removed.

1 Scope and field of application

This International Standard specifies methods for the determination of snow load on roofs.

It is intended to serve as a basis for the development of national codes for the determination of snow load on roofs.

National codes may supply statistical data of the ground snow load in the form of zone maps or tables.

The shape coefficients presented in this International Standard are prepared for design application, and may thus be directly adopted for use in national codes, unless justification for other values is available.

For examining the effect of the wind on the distribution of snow loads on roofs of unusual shapes or shapes not dealt with in this International Standard or in national standards, suitable tests carried out in a wind tunnel especially equipped for reproducing accumulation phenomena may give significant results.

Specification of standard procedures and instrumentation for measurements will not be dealt with in this International Standard.

2 Definitions and symbols

2.1 characteristic snow load on the ground, s_o (in pascals[2]) : The load which is not to be exceeded towards unfavourable values on the average once in T_r years, (i.e. extreme load of T_r years return period).

NOTE — A return period is the average interval, in years, between events which equal or exceed a given magnitude.

2.2 value of snow load on roofs, s (in pascals) : The product of the characteristic snow load on the ground and an appropriate shape coefficient.

It refers to a horizontal projection of the area of the roof.

2.3 μ_i (dimensionless) : Nominal values of the shape coefficient, taking into account snow drift, sliding snow, etc., with subscripts if necessary.

2.4 l_i (in metres) : Horizontal dimensions (see 5.2), with numerical subscripts if necessary.

2.5 h_i (in metres) : Vertical dimensions (see 5.2), with numerical subscripts if necessary.

2.6 β_i (in degrees) : Angular dimensions (see 5.2), with numerical subscripts if necessary.

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1) In meteorology the term "weight of the ground snow cover" is also used.

2) 1 Pa = 1 N/m².

3   Snow load on roofs (s)

3.1   Methods for the determination of the snow load on roofs

In this International Standard, the snow load on roofs is calculated by the formula :

$$s = \mu \, s_o$$

in which the characteristic snow load on the ground, s_o, is determined as described in clause 4, and the shape coefficient, μ, is given in clause 5.

NOTES

1   Other methods for the determination of the nominal snow load on roofs, for example long-term direct measurements, will not be treated here. Although such methods may prove to be more reliable, sufficient data are not yet available to such an extent that standardization would be of practical use.

2   The possibility of eventual impact loading on multi-level roofs due to slide should be considered by the designer.

3.2   Partial loading due to melting, sliding and snow removal

If more severe imbalances may be expected from snow removal, sliding, melting, etc. than those given in clause 5 and if other information is not available, the nominal snow load shall be applied with the load intensities according to clause 5 on any given portion of the roof area and zero load on the remainder of the area.

4   Characteristic snow load on the ground (s_o)

4.1   Method for the determination of the characteristic snow load on the ground

The characteristic snow load on the ground, s_o, is determined by statistical treatment of either directly measured snow load on the ground or, more usually, other meteorological data in the area in question.

Snow load measurements on the ground should be taken in a well sheltered area, e.g. in a deciduous forest.

Methods for the determination of the characteristic snow load on the ground, s_o, are described in annexes A and B.

For practical application, the characteristic snow load on the ground will be defined in standard step values, which will yield

basic values for the preparation of zone maps as described in 4.2.

4.2   Snow zones and maps

The methods described in annexes A and B yield basic values for a subdivision of a country into zones with constant s_o-values. It should be noted that on a small scale, a map cannot show local differences in climate even where these are known to exist. This should be noted particularly for mountainous areas, where snow load on the ground is known to increase with elevation. Observations from meteorological stations at different altitudes may serve as a guide.

When drawing a map for a standardized value of T_r, isolines or zones should be constructed to include the following set of values for the characteristic snow load on the ground (in kilopascals) :

$$0,3 - 0,5 - 0,7 - 1,0 - 1,5 - 2,0 - 2,5 - \ldots$$

5   Shape coefficients

5.1   General principles

In perfectly calm weather, falling snow would cover roofs and the ground with a uniform blanket of snow, and the design snow load could be considered as a uniformly distributed load. Truly uniform loading conditions, however, are rare and have usually only been observed in areas that are sheltered on all sides by high trees, buildings, etc. In such a case the shape coefficient would be equal to unity.

In most regions, snowfalls are accompanied or followed by winds. The winds will redistribute the snow, and on some roofs, especially multilevel roofs, the accumulated drift load may reach a multiple of the ground load. Roofs which are sheltered by other buildings, vegetation, etc., may collect more snow load than the ground load. This phenomenon is of the same nature as that illustrated for multilevel roofs in 5.2.4.

Additionally, one has to consider the sliding effect on pitched roofs. Sliding of snow depends on the thermal conditions in the roof, surface roughness, the roof angle and existing obstructions.

So far sufficient data are not available to determine the shape coefficient on a statistical basis. Therefore, a nominal value is given. A representative sample of roofs is shown in 5.2. However, special cases such as strip loading, cleaning of the roof periodically by deliberate heating of the roof, etc., have to be treated separately (see 3.2).
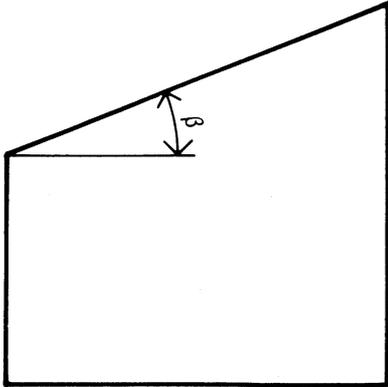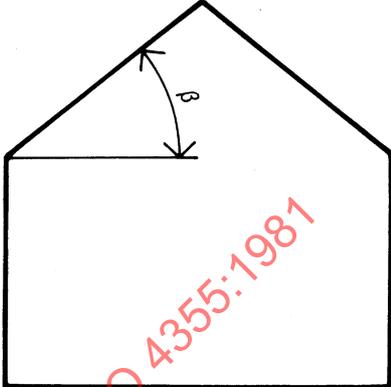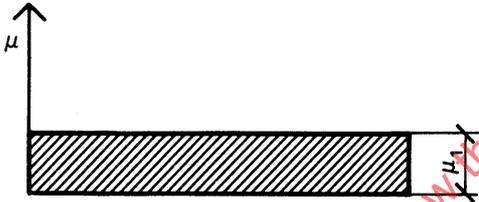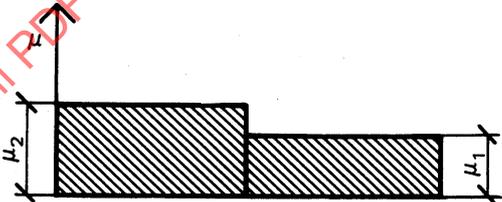
The distribution of snow in the direction parallel to the eaves is assumed to be uniform.

5.2 Shape coefficients for selected types of roofs

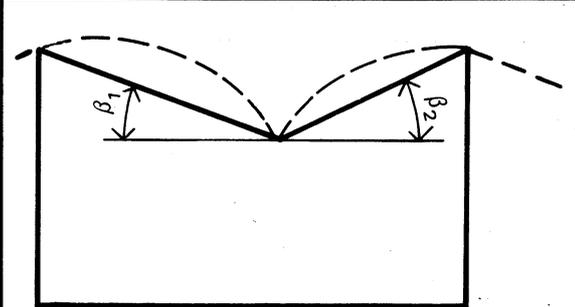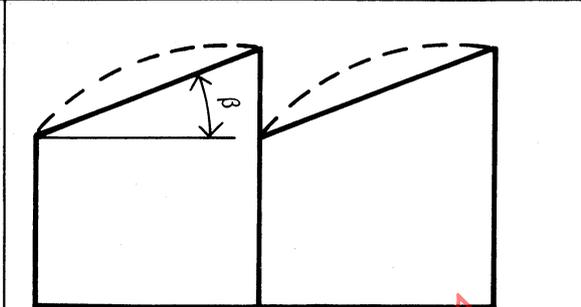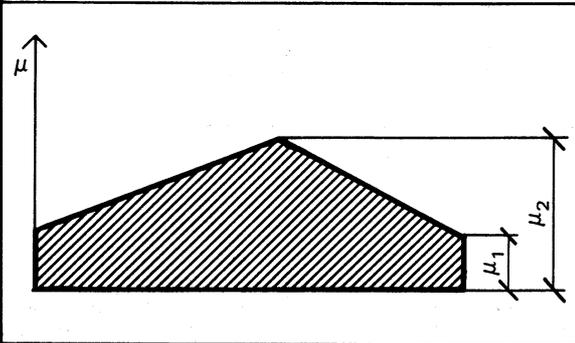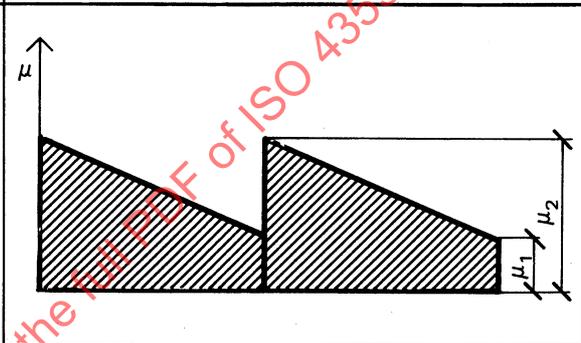| 5.2.1	Simple flat and monopitch roofs	Simple pitched roofs (positive roof slope)[1]

	Simple flat and monopitch roofs	Simple pitched roofs (positive roof slope)[1]
$0° < \beta < 15°$		$\mu_2 = \mu_1 = 0{,}8$
$15° < \beta < 30°$	$\mu_1 = 0{,}8$	$\mu_2 = 0{,}8 + 0{,}4\left(\dfrac{\beta - 15}{15}\right)$ $\mu_1 = 0{,}8$
$30° < \beta < 60°$	$\mu_1 = 0{,}8\left(\dfrac{60 - \beta}{30}\right)$	$\mu_2 = 1{,}2\left(\dfrac{60 - \beta}{30}\right)$ $\mu_1 = 0{,}8\left(\dfrac{60 - \beta}{30}\right)$
$\beta > 60°$	$\mu_1 = 0$	$\mu_2 = \mu_1 = 0$

1) For asymmetrical simple pitched roofs, each side of the roof shall be treated as one half of corresponding symmetrical roofs.
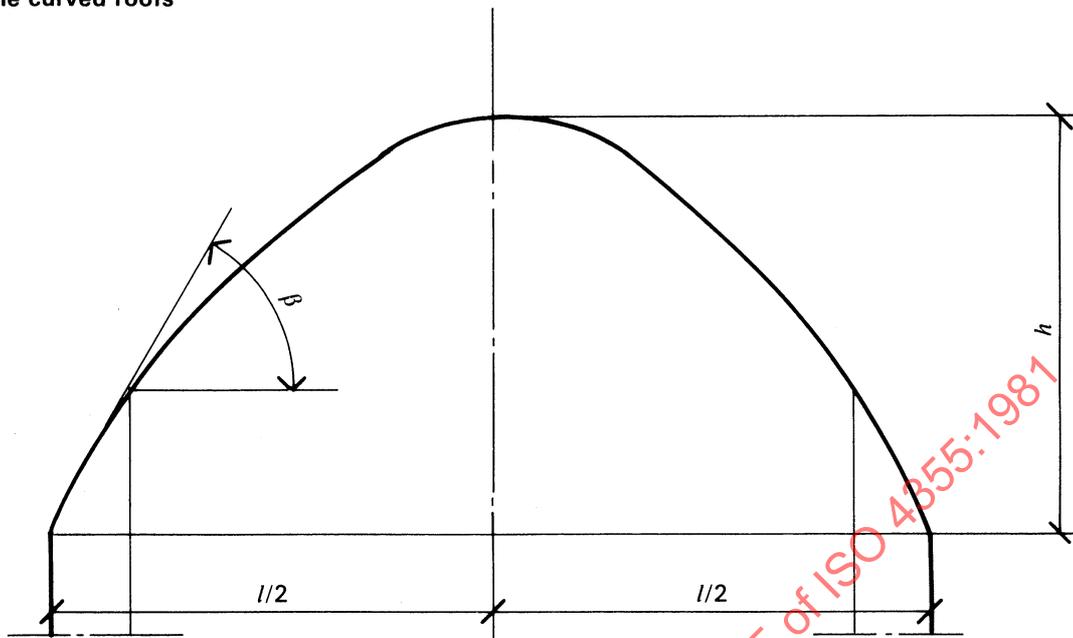
5.2.2

	Simple or multiple pitched roofs (negative roof slope)	Two-span or multispan roofs
	$\beta = \dfrac{\beta_1 + \beta_2}{2}$	
$0° < \beta < 30°$	$\mu_2 = 0{,}8 \left(\dfrac{30 + \beta}{30} \right)$ $\mu_1 = 0{,}8$	$\mu_2 = 0{,}8 \left(\dfrac{30 + \beta}{30} \right)$ $\mu_1 = 0{,}8$
$30° < \beta < 60°$	$\mu_2 = 1{,}6$ $\mu_1 = 0{,}8 \left(\dfrac{60 - \beta}{30} \right)$	$\mu_2 = 1{,}6$ $\mu_1 = 0{,}8 \left(\dfrac{60 - \beta}{30} \right)$
$\beta > 60°$	$\mu_2 = 1{,}6$ $\mu_1 = 0$	$\mu_2 = 1{,}6$ $\mu_1 = 0$

5.2.3 Simple curved roofs

The following cases, 1 and 2, must be examined :

Case 1

$\mu_1 = 0,8$

Case 2

$\mu_2 = 0,3 + 10\dfrac{h}{l}$
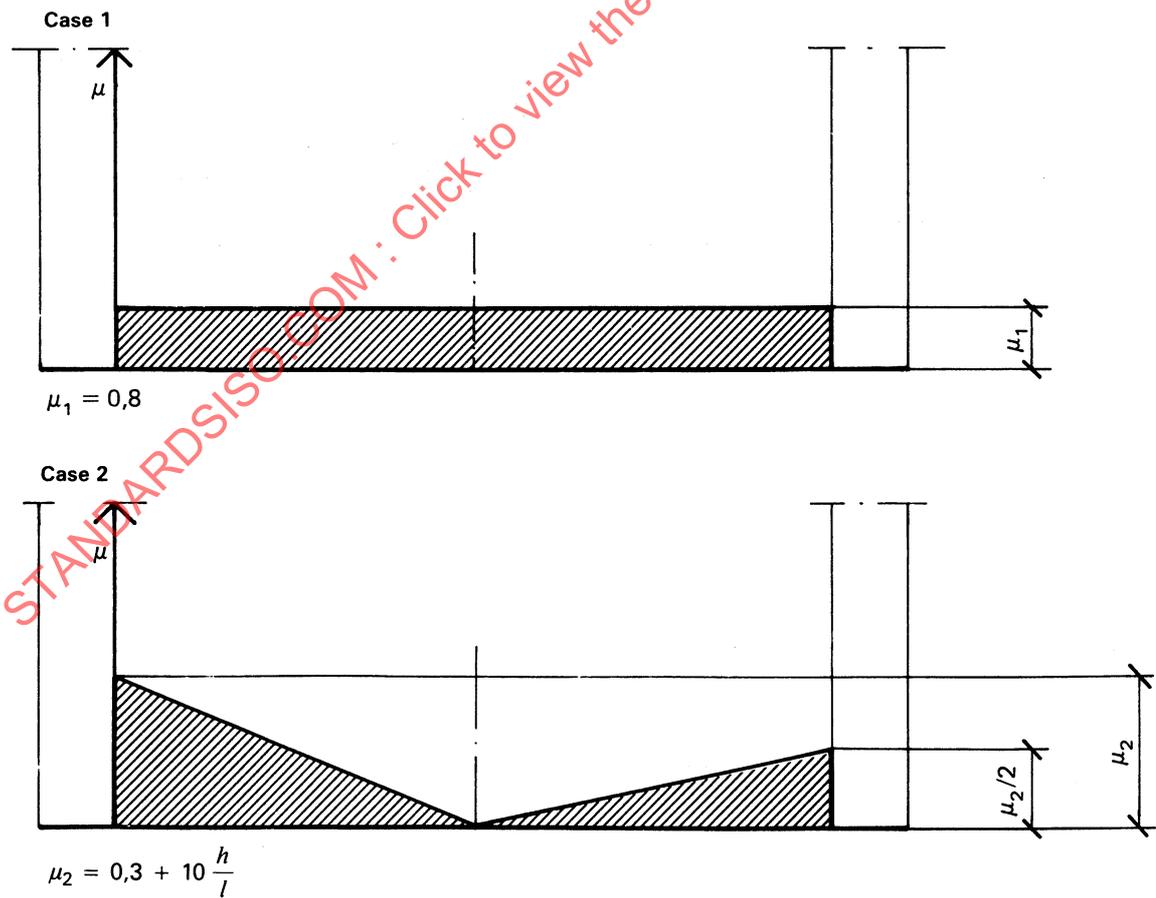
Restriction :

$\mu_2 \leqslant 2,3$
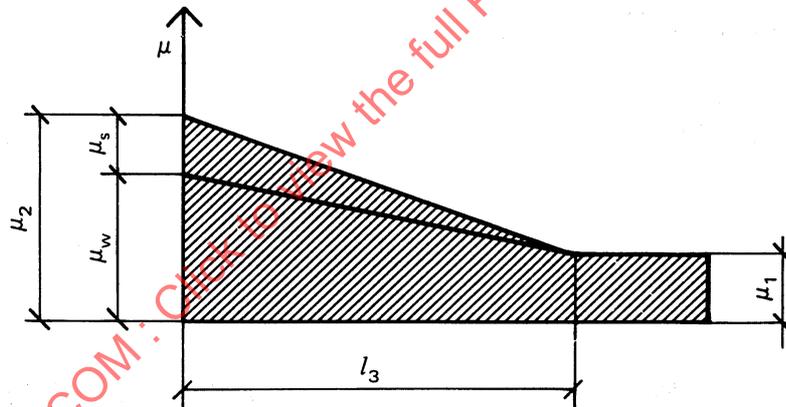
$\mu = 0$ if $\beta > 60°$

5.2.4 Multilevel roofs[1]

$\mu_1 = 0,8$

$\mu_2 = \mu_s + \mu_w$
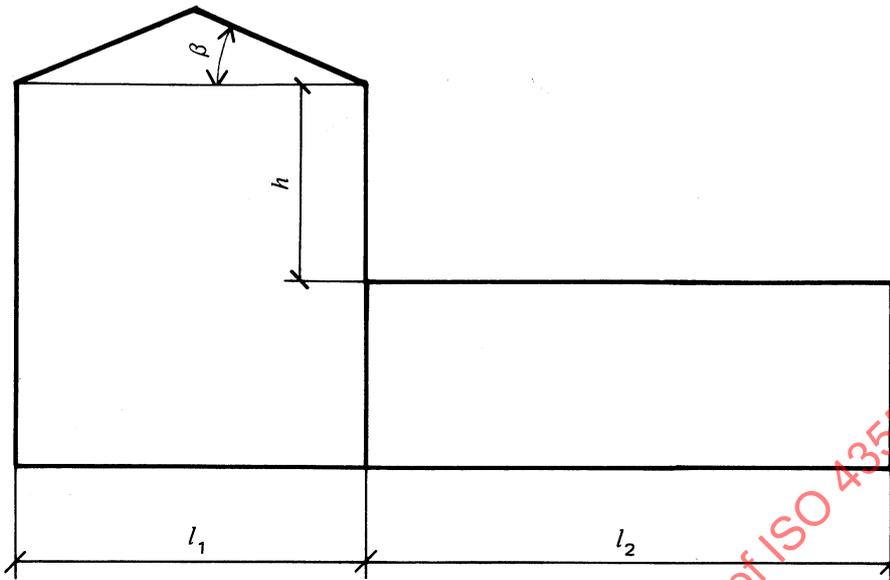
where

μ_s : due to sliding

μ_w : due to wind

$l_3 = 2\,h^{2)}$ but is restricted as follows :

$5\,\text{m} < l_3 < 15\,\text{m}$

$$\mu_w = \frac{l_1 + l_2}{2\,h} < \frac{kh}{s_o}$$

with the restriction $0,8 < \mu_w < 4,0$

where

h is in metres

s_o is in kilopascals (kilonewtons per square metre)

k $= 2\,\text{kN/m}^3$

$\beta > 15°$: μ_s is determined from an additional load amounting to 50 % of the maximum total load on the adjacent slope of the upper roof[3], and is distributed linearly as shown on the figure.

$\beta < 15°$: $\mu_s = 0$

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1) A more extensive formula for μ_w is described in annex C.

2) If $l_2 < l_3$ the coefficient μ is determined by interpolation between μ_1 and μ_2.

3) The load on the upper roof is calculated according to 5.2.1 or 5.2.2.

5.2.5 Complex multilevel roofs

$l_2 + l_3 < l_1$

$l_2 = 2\,h_1;\ l_3 = 2\,h_2;\ \mu_1 = 0.8$

$l_2 + l_3 > l_1$
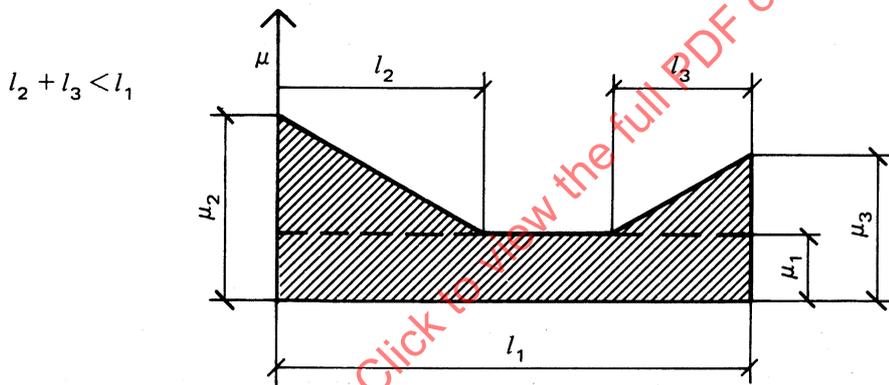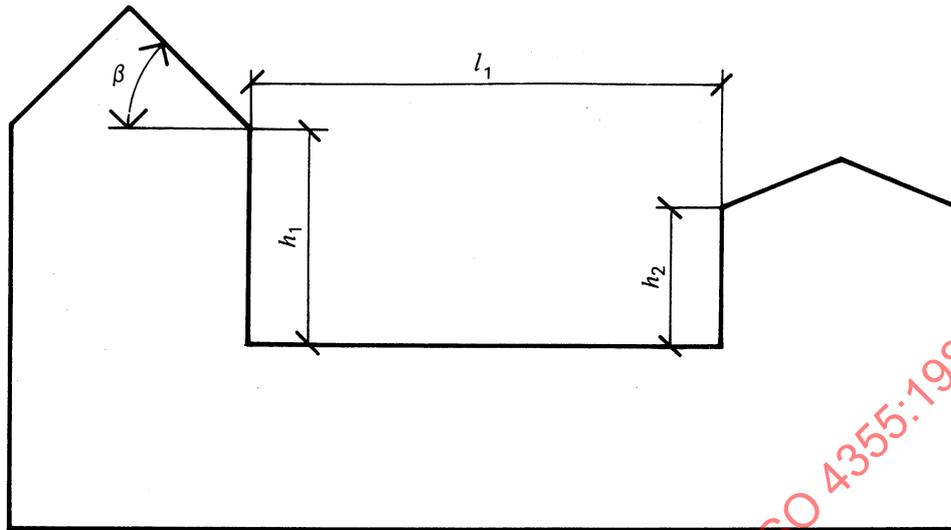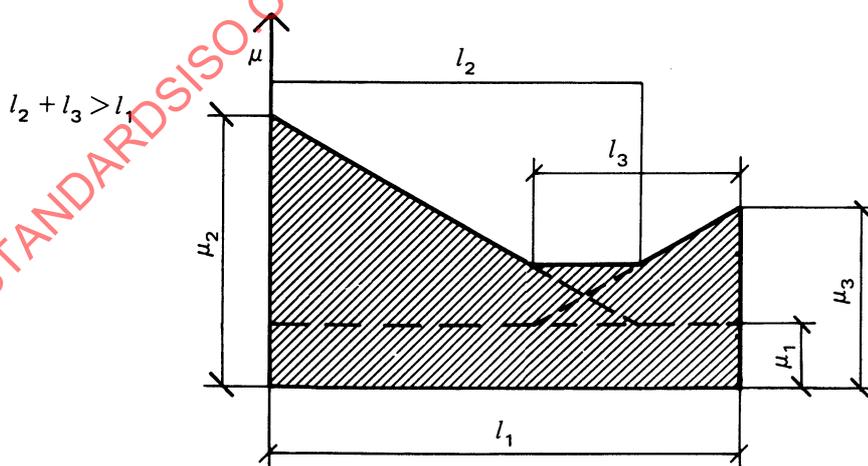
$l_2 = 2\,h_1;\ l_3 = 2\,h_2;\ \mu_1 = 0.8$

Restriction :

$5\ \text{m} < l_2 < 15\ \text{m};$

$5\ \text{m} < l_3 < 15\ \text{m}$

μ_2 and μ_3, $(\mu_s + \mu_w)$, are calculated according to 5.2.1, 5.2.2 and 5.2.4.

5.2.6 Roofs with local projections and obstructions
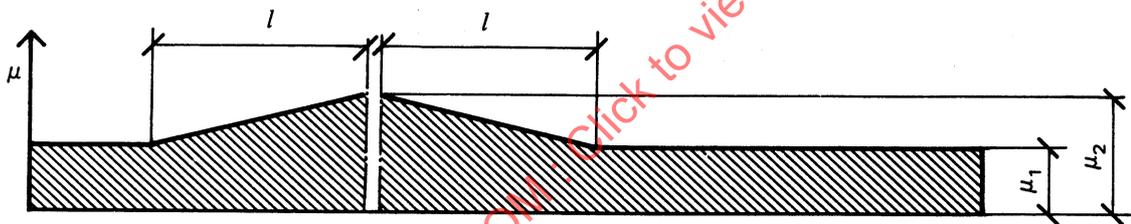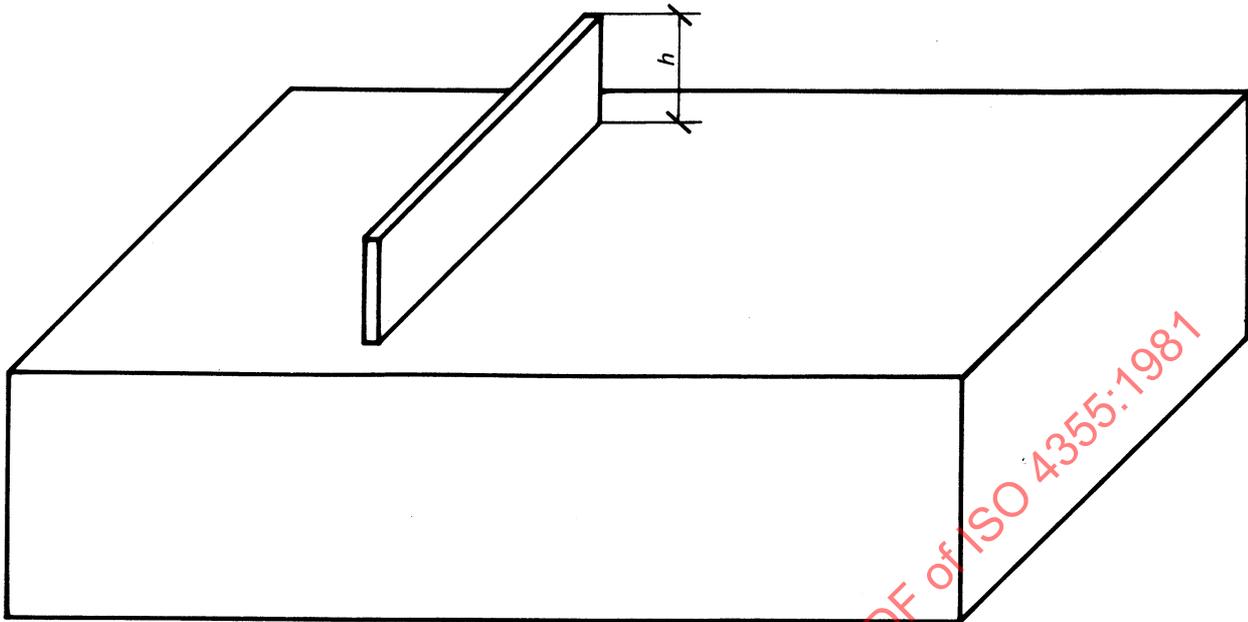
$$\mu_2 = \frac{kh}{s_o}$$

where

  h is in metres

  s_o is in kilopascals (kilonewtons per square metre)

  k = 2 kN/m³

  μ_1 = 0,8

  l = 2 h

Restrictions :

  0,8 < μ_2 < 2,0

  5 m < l < 15 m

5.3 Shape coefficients in areas exposed to wind

The shape coefficient μ_1 in 5.2 and annex C may be reduced by 25 % provided the designer has demonstrated that the following conditions are fulfilled :

a) the building is located in an exposed location such as open level terrain with only scattered buildings, trees or other obstructions, so that the roof is exposed to the winds on all sides and is not likely to become shielded in the future by obstructions higher than the roof within a distance from the building equal to ten times the height of the obstruction above the roof level;

b) the roof does not have any significant projections such as parapet walls which may prevent snow from being blown off the roof.

NOTE — In some areas, winter climate may not be of such a nature as to produce a significant reduction of roof loads from the snow load on the ground. These areas are :

a) winter calm valleys in the mountains where sometimes layer after layer of snow accumulates on roofs without any appreciable removal of snow by wind;

b) areas (i.e. high temperature) where the maximum snow load may be the result of a single snowstorm, occasionally without appreciable wind removal.

In such areas, the determination of the shape coefficients shall be based on local experience with due regard to the likelihood of wind drifting and sliding.

Annex A

Statistical treatment of the snow load values

For the design of structures, it is the maximum load every year which is of interest. Records of annual maxima should be subjected to statistical analysis to determine the required characteristic values. Unless analysis of the data indicates otherwise, the Gumbel [1] distribution Type 1 is recommended as a suitable distribution curve for annual maximum snow load.

NOTE — In some regions it is frequently observed that there is no snowfall in certain years. In this case the distribution of the annual maximum snow load is not well represented by a law of Type 1. The use of a law of Type 1 can, however, be envisaged on condition that the sample is limited only to those years when a snowfall of some kind has been observed. The annual frequency of exceeding a given value of the snow load is then equal to the product of

a) the frequency of the years in which snow falls,

by

b) the annual frequency of exceeding the given load,

the latter frequency being calculated using only the years with snowfall.

The following describes an analytical procedure using this distribution and fitting it to the observations by the method of least squares.

NOTE — The difficulties inherent in using meteorological measurements should be noted. The degree of significance of these values varies from one meteorological station to another, mainly because of the local measuring conditions. In addition, the statistical results are necessarily adversely affected by uncertainty resulting from the smallness of the samples considered; an interpretation of the statistical results is necessary, in particular comparing the values obtained at several neighbouring stations, in order to offset the uncertainties resulting from the measuring conditions and the statistical analysis itself. Finally, it should not be forgotten that the action and its effects also depend on the variability of the density of the snow with the result that the action return periods and their effects may differ considerably from the height return periods; corrections of the statistical results may thus be necessary.

The probability distribution of x is :

$$F(x) = \exp\left(- e^{-y}\right) \qquad \ldots (1)$$

where

$$y = \frac{x - a}{b}$$

$$b = \frac{\sigma}{\sigma_N}$$

$$a = \bar{x} - \sigma \frac{\bar{y}_N}{\sigma_N}$$

where

$\bar{x}$ and σ are the arithmetic mean and standard deviation of the observed extremes;

$\bar{y}_N$ and σ_N are functions of the sample size N (the latter usually being the number of years of observation), and called reduced mean and reduced standard deviation respectively.

$\bar{y}_N$ and σ_N are both tabulated (see tables 1 and 2).

The return period, T_r, the average interval in years between events which equal or exceed a given magnitude, can be written approximately :

$$T_r = \frac{1}{1 - F(s_o)} \qquad \ldots (2)$$

where $F(s_o)$ is the distribution function for the annual maximum snow load.

When the probability or return period is given, the characteristic snow load on the ground, s_o, is given by :

$$s_o = a - b \ln \left\{ - \ln \left[F(s_o) \right] \right\} \qquad \ldots (3)$$

$F(s_o)$ is the chosen a priori value of probability (for example 0,95 corresponding to a 20-year return period).

Another way of fitting data to the extreme value distribution consists of plotting data on suitable graph paper (figure 1), known as extreme probability paper, and drawing the best-fitting straight line.

Points are commonly determined by the formula :

$$T_r = \frac{n + 1}{m} \qquad \ldots (4)$$

where

n is the number of years of record;

m is the rank of the item in the series, m being 1 for the largest.

This formula is an approximate expression for the mean value of a series of observations of the m-th in rank out of n values.

Table 1 — Reduced mean $\bar{y}_N$

N	0	1	2	3	4	5	6	7	8	9
10	0,495 2	0,499 6	0,503 5	0,507 0	0,510 0	0,512 8	0,515 7	0,518 1	0,520 2	0,522 0
20	0,523 6	0,525 2	0,526 8	0,528 3	0,529 6	0,530 9	0,532 0	0,533 2	0,534 3	0,535 3
30	0,536 2	0,537 1	0,538 0	0,538 8	0,539 6	0,540 3	0,541 0	0,541 8	0,542 4	0,543 0
40	0,543 6	0,544 2	0,544 8	0,545 3	0,545 8	0,546 3	0,546 8	0,547 3	0,547 7	0,548 1
50	0,548 5	0,548 9	0,549 3	0,549 7	0,550 1	0,550 4	0,550 8	0,551 1	0,551 5	0,551 8
60	0,552 1	0,552 4	0,552 7	0,553 0	0,553 3	0,553 5	0,553 8	0,554 0	0,554 3	0,554 5
70	0,554 8	0,555 0	0,555 2	0,555 5	0,555 7	0,555 9	0,556 1	0,556 3	0,556 5	0,556 7
80	0,556 9	0,557 0	0,557 2	0,557 4	0,557 6	0,557 8	0,558 0	0,558 1	0,558 3	0,558 5
90	0,558 6	0,558 7	0,558 9	0,559 1	0,559 2	0,559 3	0,559 5	0,559 6	0,559 8	0,559 9
100	0,560 0									

Table 2 — Reduced standard deviation σ_N

| N	0	1	2	3	4	5	6	7	8	9
10	0,949 7	0,967 6	0,983 3	0,997 2	1,009 5	1,020 6	1,031 6	1,041 1	1,049 3	1,056 5
20	1,062 8	1,069 6	1,075 4	1,081 1	1,086 4	1,091 5	1,096 1	1,100 4	1,104 7	1,108 6
30	1,112 4	1,115 9	1,119 3	1,122 6	1,125 5	1,128 5	1,131 3	1,133 9	1,136 3	1,138 8
40	1,141 3	1,143 6	1,145 8	1,148 0	1,149 9	1,151 9	1,153 8	1,155 7	1,157 4	1,159 0
50	1,160 7	1,162 3	1,163 8	1,165 3	1,166 7	1,168 1	1,169 6	1,170 8	1,172 1	1,173 4
60	1,174 7	1,175 9	1,177 0	1,178 2	1,179 3	1,180 3	1,181 4	1,182 4	1,183 4	1,184 4
70	1,185 4	1,186 3	1,187 3	1,188 1	1,189 0	1,189 8	1,190 6	1,191 5	1,192 3	1,193 0
80	1,193 8	1,194 5	1,195 3	1,195 9	1,196 7	1,197 3	1,198 0	1,198 7	1,199 4	1,200 1
90	1,200 7	1,201 3	1,202 0	1,202 6	1,203 2	1,203 8	1,204 4	1,204 9	1,205 5	1,206 0
100	1,206 5									
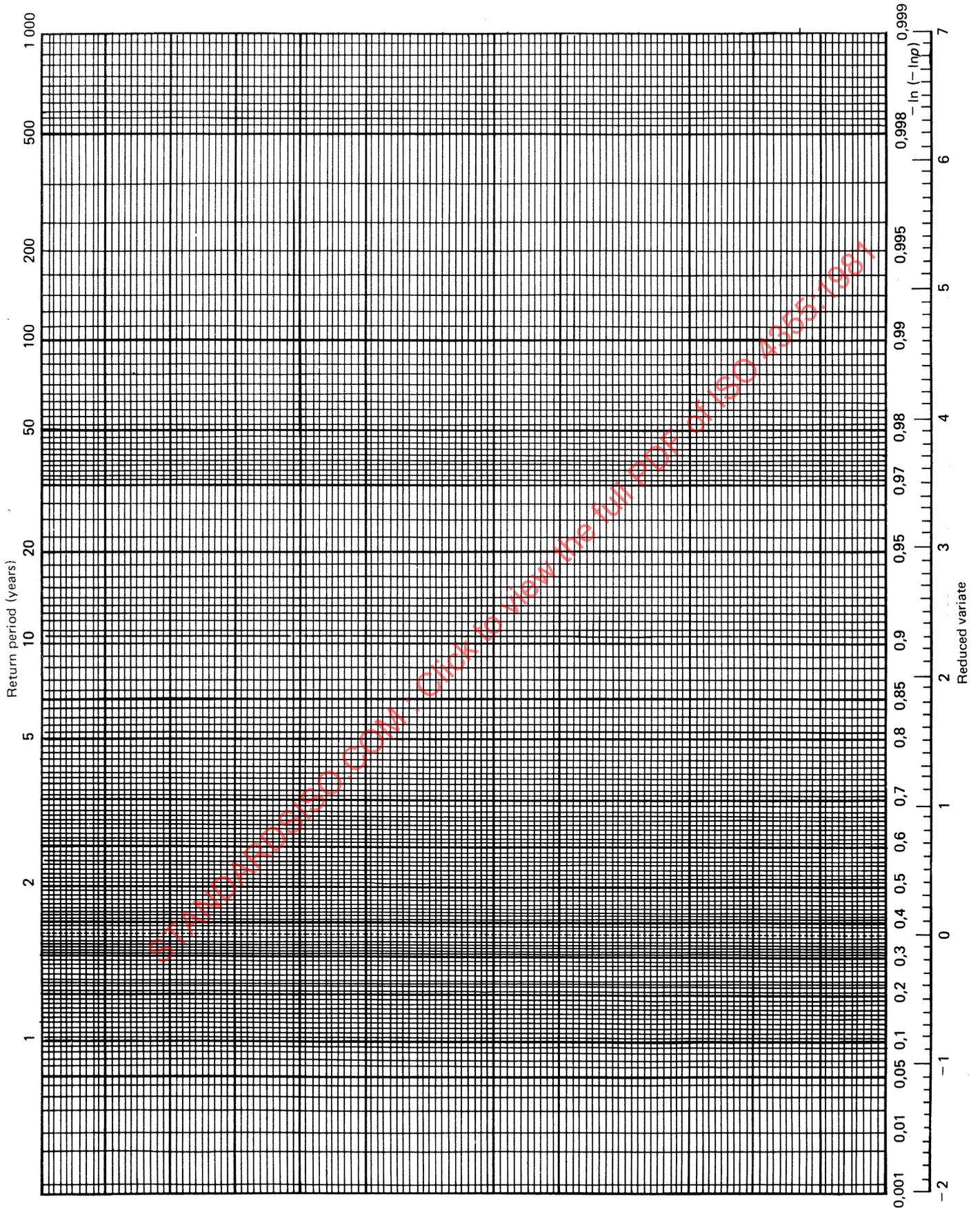
Figure 1 — Extreme probability paper
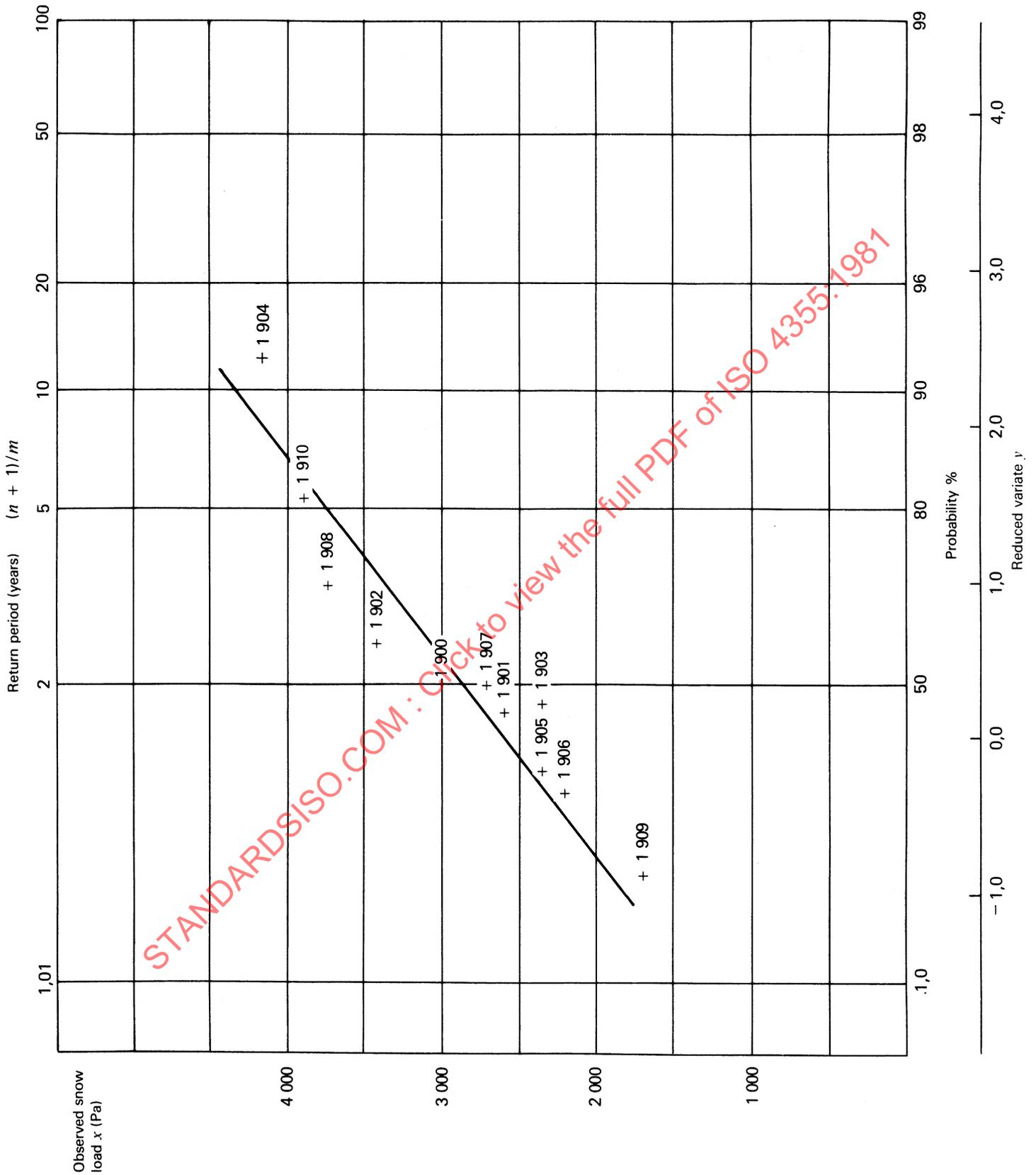
Figure 2 — Example of extreme probability plot