Section 9 Eurocode 1 EN 1991-1-3: Annex C, Annex D

9.1 Annex C: European Ground Snow Load Maps

This Annex presents the European snow maps which are the result of scientific work carried out under contract to DGIII/D-3 of the European Commission, by a specifically formed research Group. The objectives of this Annex, defined in 1.1(5), are:

— to help National Competent Authorities to redraft their national maps

— to establish harmonised procedures to produce the maps.

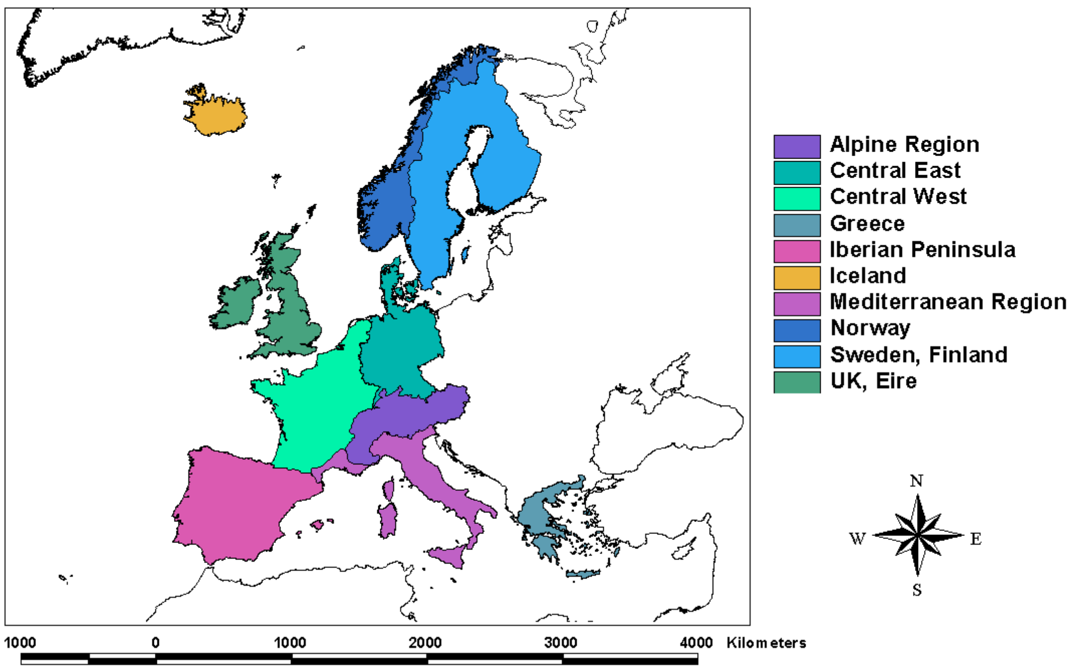

Figure 9.55 From Figure C.1 - European Climatic regions.

This will eliminate or reduce the inconsistencies of snow load values in CEN member states and at borderlines between countries. The European snow map developed by the Research Group are divided into 9 different homogeneous climatic regions, as shown in Figures C.1 to C.10.

Climatic Region	Expression
Alpine Region:	$s_k = (0,642Z + 0,009)\left[1 + \left(\frac{A}{728}\right)^2\right]$
Central East:	$s_k = (0,264Z - 0,002)\left[1 + \left(\frac{A}{256}\right)^2\right]$
Greece:	$s_k = (0,420Z - 0,030)\left[1 + \left(\frac{A}{917}\right)^2\right]$
Iberian Peninsula:	$s_k = (0,190Z - 0,095)\left[1 + \left(\frac{A}{524}\right)^2\right]$
Mediterranean Region:	$s_k = (0,498Z - 0,209)\left[1 + \left(\frac{A}{452}\right)^2\right]$
Central West:	$s_k = 0,164Z - 0,082 + \frac{A}{966}$
Sweden, Finland:	$s_k = 0,790Z + 0,375 + \frac{A}{336}$
UK, Republic of Ireland:	$s_k = 0,140Z - 0,1 + \frac{A}{501}$

Table 9.22 From Table C.1 - Altitude - Snow Load Relationships.

In each climatic region a given load-altitude correlation formula applies and this is given in Table C.1 above where:

- s_k is the characteristic snow load on the ground $[kN/m^2]$
- A is the site altitude above Sea Level [m]
- Z is the zone number given on the map (1; 2; 3; 4; 4,5).

9.2 Annex D: Adjustment of the ground snow load according to return period

Ground level snow loads for any mean recurrence interval different to that for the characteristic snow load, s_k, (which by definition is based on annual probability of exceedence of 0,02) may be adjusted to correspond to characteristic values by application of Sections D(2) to D(4). If the available data show that the annual maximum snow load can be assumed to follow a Gumbel probability distribution, then the relationship between the characteristic value of the snow load on the ground and the snow load on the ground for a mean recurrence interval of n years is given by the formula (D.1):(1)

$$\frac{s_n}{s_k} = \left\{ \frac{1 - V\frac{\sqrt{6}}{\pi} \cdot [\ln(-\ln(1-P_n)) + 0,57722]}{1 + 2,5923V} \right\}$$

where:

- s_k is the characteristic snow load on the ground (with a return period of 50 years, in accordance with EN 1990:2002)
- s_n is the ground snow load with a return period of n years
- P_n is the annual probability of exceedence (equivalent to approximately $1/n$, where n is the corresponding recurrence interval (years))
- V is the coefficient of variation of annual maximum snow load(2).

However, expression (D.1) should not be applied for annual probabilities of exceedence greater than 0,2 (i.e. return period less than approximately 5 years). Where permitted by the relevant national Authority expression (D.1) may also be adapted to calculate snow loads on the ground for other probabilities of exceedence. For example for:

a. structures where a higher risk of exceedence is deemed acceptable
b. structures where greater than normal safety is required.

9.3 Verification tests

EN1991-1-3_(C).XLS. 8.40 MB. Created: 09 March 2013. Last/Rel.-date: 09 March 2013. Sheets:

— Splash
— Annex C
— Annex D.

EXAMPLE 9-AU- European Ground Snow Load Maps - **test 1**

Given: Assuming $A = 100$ mamsl (*meters above mean sea level*) and zone number $Z = 2$, find the characteristic snow load on the ground s_k for all the climatic regions on Table C.1 "*Altitude - Snow Load Relationship*".

[*Reference sheet:* Annex C]-[*Cell-Range: A53:O53-A100:O100*].

(1) Where appropriate another distribution function for the adjustment of return period of ground snow load may be defined by the relevant national Authority.

(2) Information on the coefficient of variation may be given by the relevant national Authority.

Solution: Alpine Region:

$$s_k = (0,642Z + 0,009)\left[1 + \left(\frac{A}{728}\right)^2\right] = (0,642 \cdot 2 + 0,009)\left[1 + \left(\frac{100}{728}\right)^2\right] = 1,32 \ \text{kN/m}^2 .$$

Central East:

$$s_k = (0,264Z - 0,002)\left[1 + \left(\frac{A}{256}\right)^2\right] = (0,264 \cdot 2 - 0,002)\left[1 + \left(\frac{100}{256}\right)^2\right] = 0,61 \ \text{kN/m}^2 .$$

Greece:

$$s_k = (0,420Z - 0,030)\left[1 + \left(\frac{A}{917}\right)^2\right] = (0,420 \cdot 2 - 0,030)\left[1 + \left(\frac{100}{917}\right)^2\right] = 0,82 \ \text{kN/m}^2 .$$

Iberian Peninsula:

$$s_k = (0,190Z - 0,095)\left[1 + \left(\frac{A}{524}\right)^2\right] = (0,190 \cdot 2 - 0,095)\left[1 + \left(\frac{100}{524}\right)^2\right] = 0,30 \ \text{kN/m}^2 .$$

Mediterranean Region:

$$s_k = (0,498Z - 0,209)\left[1 + \left(\frac{A}{452}\right)^2\right] = (0,498 \cdot 2 - 0,209)\left[1 + \left(\frac{100}{452}\right)^2\right] = 0,83 \ \text{kN/m}^2 .$$

Central West:

$$s_k = 0,164Z - 0,082 + \frac{A}{966} = 0,164 \cdot 2 - 0,082 + \frac{100}{966} = 0,35 \ \text{kN/m}^2 .$$

Sweden, Finland:

$$s_k = 0,790Z + 0,375 + \frac{A}{336} = 0,790 \cdot 2 + 0,375 + \frac{100}{336} = 2,25 \ \text{kN/m}^2 .$$

UK, Republic of Ireland:

$$s_k = 0,140Z - 0,1 + \frac{A}{501} = 0,140 \cdot 2 - 0,1 + \frac{100}{501} = 0,38 \ \text{kN/m}^2 .$$

example-end

EXAMPLE 9-AV- European Ground Snow Load Maps - **test 2**

Given: Assuming $A = 200$ mamsl, $Z = 2$, $C_e = 1$, $C_t = 1$ find for the UK:

1) the characteristic ground snow load s_k

2) the design value of exceptional snow load on the ground for locations where exceptional snow loads on the ground can occur

3) the snow load on roofs for the persistent/transient design situations

4) the snow load on roofs for the accidental design situations where exceptional snow load is the accidental action

5) the snow load on roofs for the accidental design situations where exceptional snow drift is the accidental action and where Annex B applies.

[*Reference sheet:* Annex C]-[*Cell-Range: A102:O102-A150:O150*].

Plot: s_k = 0,140·Z – 0,1 + A/501 = f(A; Z = 2)

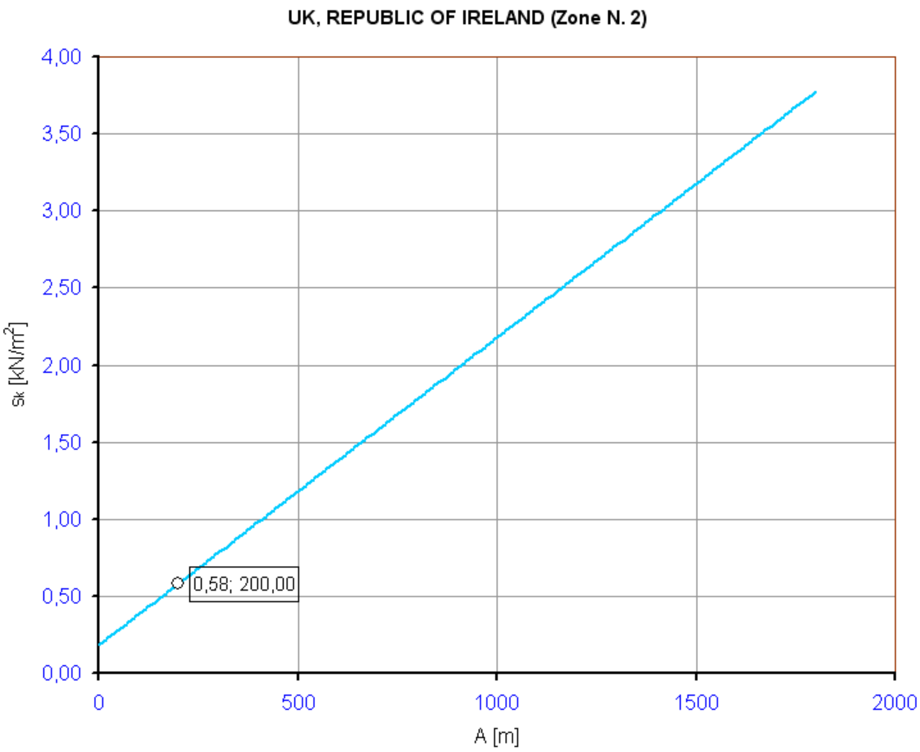

Figure 9.56 Characteristic ground snow load for UK and Republic of Ireland (zone N. 2).

Solution: **1)** UK, Republic of Ireland:

$$s_k = 0,140Z - 0,1 + \frac{A}{501} = 0,140 \cdot 2 - 0,1 + \frac{200}{501} = 0,58 \text{ kN/m}^2 .$$

2) With a coefficient for exceptional snow loads equal to $C_{esl} = 2$:

$$s_{Ad} = C_{esl} \cdot s_k = 2 \cdot 0,58 = 1,16 \text{ kN/m}^2 .$$

3) With $C_e = 1$, $C_t = 1$: $s = \mu_1 \cdot C_2 \cdot C_t \cdot s_k = \mu_1 \cdot 1 \cdot 1 \cdot 0,58 = \mu_1 \cdot 0,58 \text{ kN/m}^2$.

4) With $s_{Ad} = 1,16 \text{ kN/m}^2$: $s = \mu_1 \cdot C_e \cdot C_1 \cdot s_{Ad} = \mu_1 \cdot 1,16 \text{ kN/m}^2$.

5) $s = \mu_1 \cdot s_k = \mu_1 \cdot 0,58 \text{ kN/m}^2$.

example-end

EXAMPLE 9-AW- Adjustment of the ground snow load according to return period - **test 3**

Given: According to Annex D, find the ratio s_n/s_k for a coefficient of variation of annual maximum snow load $V = 0,5$ and a recurrence interval equal to $n = 90$ years.

[*Reference sheet:* Annex D]-[*Cell-Range: A15:O15-A31:O31*].

Solution: From eq. D.1 with $P_n = 1/n = 1/90 \approx 0,0111$:

$$\frac{s_n}{s_k} = \left\{ \frac{1 - V\frac{\sqrt{6}}{\pi} \cdot [\ln(-\ln(1 - P_n)) + 0,57722]}{1 + 2,5923V} \right\} = \left\{ \frac{1 - 0,5\frac{\sqrt{6}}{\pi} \cdot \left[\ln\left(-\ln\left(1 - \frac{1}{90}\right)\right) + 0,57722\right]}{1 + 2,5923 \cdot 0,5} \right\},$$

$$\frac{s_n}{s_k} = \frac{2,527}{2,296} \approx 1,10 .$$

Graph of eq. (D.1) with V = 0,5.

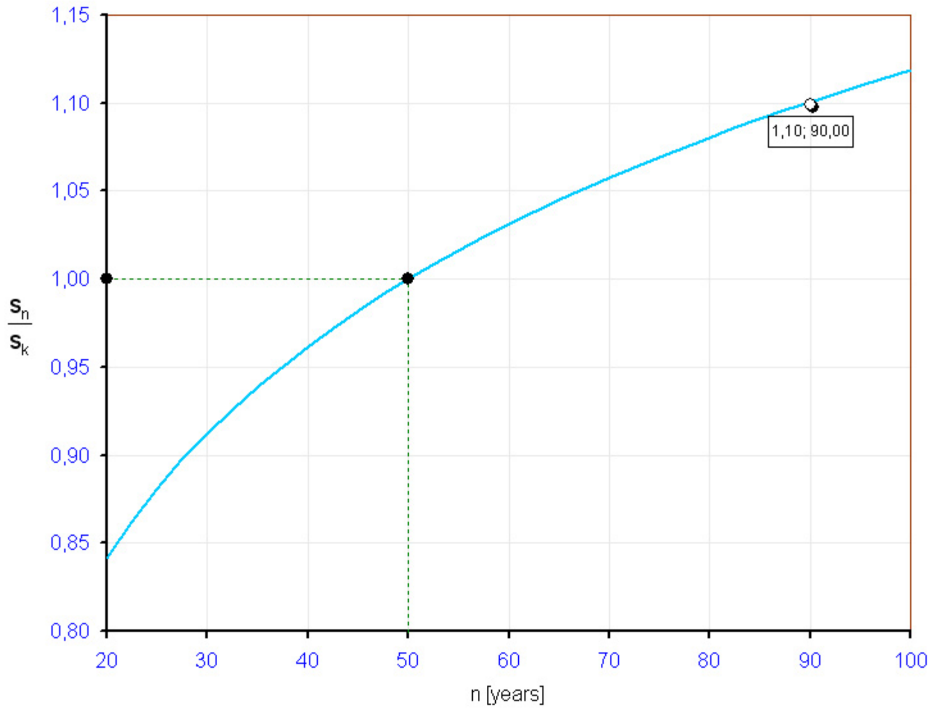

Figure 9.57 Ratio s_n/s_k with V = 0,5 plotted against "n" (years).

For a characteristic snow load on the ground equal to $s_k = 0,58$ kN/m^2 (return period of 50 years), we get ($n = 90$ years):

$s_n = 1,10 \cdot s_k = 1,10 \cdot 0,58 = 0,64$ kN/m^2.

example-end

9.4 References [Section 9]

Derivation of snow load, Technical Guidance Note, TheStructuralEngineer, March 2012. Web resource: www.istructe.org/resources-centre/library.

EN 1991-1-3:2003/AC:2009. Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads. Brussels: CEN/TC 250 - Structural Eurocodes, March 2009.

EN 1991-1-3:2003. Eurocode 1 - Actions on structures - Part 1-3: General actions - Snow loads. Brussels: CEN/TC 250 - Structural Eurocodes, July 2003 (DAV).

EN 1991-1-3 (2003) (English): Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC].

Manual for the design of building structures to Eurocode 1 and Basis of Structural Design April 2010. © 2010 The Institution of Structural Engineers.

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