Multi-span Roof in FprEN 1991-1-3: 2023, 7.5.4
Summary of the comments

Roof snow load F**prEN 1991-1-3: 2023**, 7.2, Equation (7.1) or (7.2): $\mathbf{s = \mu_i \cdot C_t \cdot s_k}$ (or s_{Ad})

Roof snow height (calculated equivalently using $\gamma = 2$ in kN/m³ (NDP)): $\mathbf{d = s / \gamma = \mu_i} \cdot C_t \cdot \mathbf{s_k} / \gamma$

Selection of C_e and C_t:

7.3, Table 7.1 otherwise (NDP)

7.4 (2), (3), (4) for all (NDP), otherwise $C_t = 1$

<table>
<tr><th>No.</th><th>Existing text</th><th>Comment</th><th>Proposed action + corrected text</th></tr>
<tr>
<td>5
(i)</td>
<td>(1) The balanced load arrangement that should be used for multi-span roofs is shown in Figure 7.6 case (i), the snow load shape coefficient $\mu_2(\alpha, C_e)$ being given by Formula (7.7) for case (i).</td>
<td>The calculation of the snow load distribution for Figure (7.6), case (i) does not match the representation of the snow load distribution in Figure (7.6). The shape coefficient μ_2 (30°, 1) for the roof valley is inconsistent.
Wat was the intention of C_e = 1? A reduction of the drift losses out of the valley in comparison to drift losses from a flat roof??? If this is the case, this regulation does NOT suffice, as shown in Fig. 1.
<table>
<tr><td colspan="5">For roof angles α ≤ 30°
According to FprEN 1991-1-23; 2023, 7.5.4 (1): with reference to Case (i), Formula (7.7)</td></tr>
<tr><td>Exposure Coefficient C_e</td><td>Shape Coefficient Outer Pitches α ≤ 30° (windward, leeward) Figure 7.6 (i)</td><td></td><td>Shape Coefficient Valley Inner Roof Pitches Figure 7.6 (i)</td><td>Comparison</td></tr>
<tr><td>Table 7.1 (NDP)</td><td>Formula (7.7), Case (i)</td><td></td><td>Figure 7.6, Case (i)</td><td></td></tr>
<tr><td>$C_e = 1{,}2$</td><td>$\mu_{2,b} = 0{,}8\ C_e$ * = 0,96</td><td>></td><td>μ_2 (30°,1) = 0,8</td><td>wrong</td></tr>
<tr><td>$C_e = 1$</td><td>$\mu_{2,b} = 0{,}8\ C_e$ * = 0,8</td><td>=</td><td>μ_2 (30°,1) = 0,8</td><td>Not intended</td></tr>
<tr><td>$C_e = 0{,}8$</td><td>$\mu_{2,b} = 0{,}8\ C_e$ * = 0,64</td><td><</td><td>μ_2 (30°,1) = 0,8</td><td>Formally correct</td></tr>
<tr><td colspan="5"><i>Note</i> *: Also, for α > 30° the regulation can also be <i>formally correct,</i> see also Fig. 1.</td></tr>
</table>
Table 1: Inconsistency prEN 1991-1-3: 2023, 7.5.4, case (i)

If the drift losses from the valley are to be reduced in comparison to a flat roof, the evenly distributed snow depth there should be larger than on the outer pitch with usual conditions for pitched roofs. Therefore, a special value $C_{e,T}$ for the valley, adapted to C_e, should be defined.
Drift surcharges or losses should always be a National Choice.</td>
<td><i>In Figure (7.6), case (i):</i>
<i>Replace:</i> μ_2 (30°, 1)
<i>by:</i> μ_2 (30°, $\mathbf{C_{e,T}}$)

<i>Add a note in Paragraph (1):</i>
NOTE The exposure coefficient for the valley (trough) of the multi-span roof $C_{e,T}$ is $(1{,}25 + C_e)/2$, unless the National Annex gives a different value.

Alternatively, the worst case could be set as a standard, to encourage National regulations:

<i>Add a note in Paragraph (1):</i>
NOTE The exposure coefficient for the valley (trough) of the multi-span roof is $\mathbf{C_{e,T} = 1{,}25}$, unless the National Annex gives a different value.</td>
</tr>
</table>

Note: **ISO 4355: 2013**, **ASCE 7-16** or **NBCC 2015** do not reduce the drift losses for the balanced load case (case (i) in FprEN 19991-1-3: 2023), only for the unbalanced load case (case (ii))!!!
In this case for case (i) $C_{e,T} = C_e$ applies.

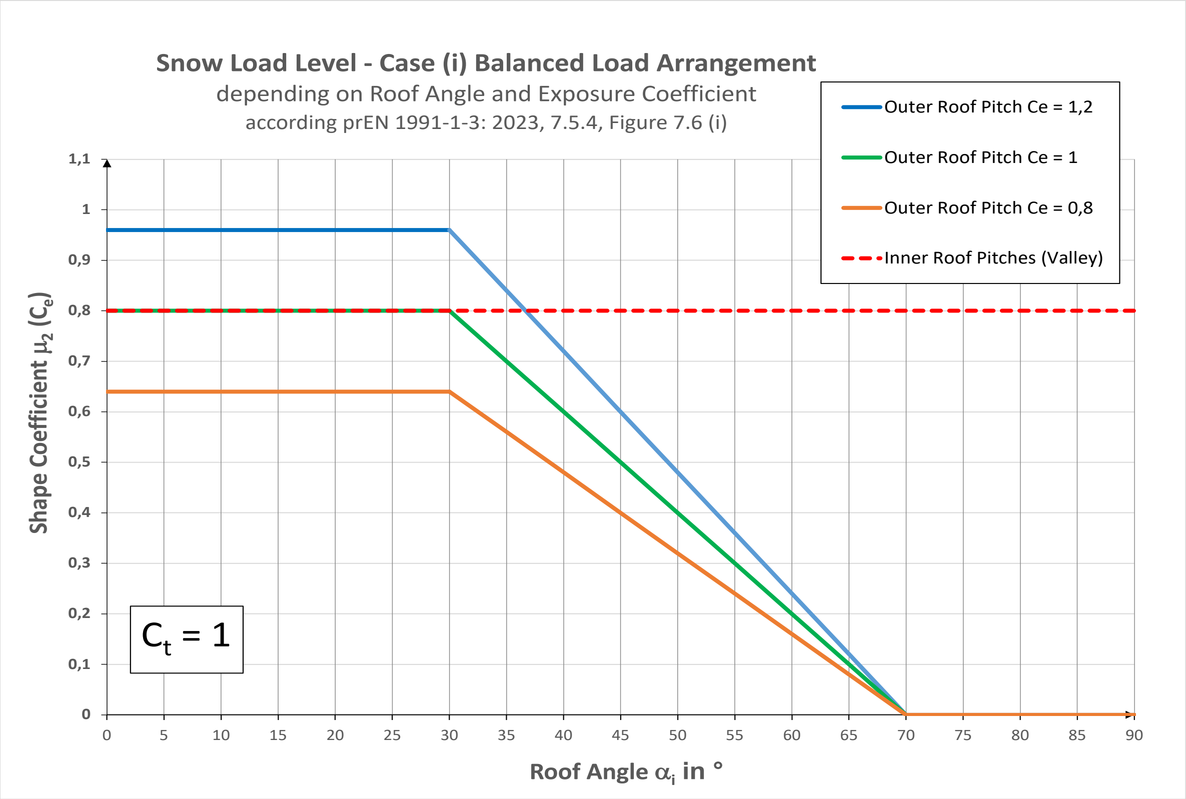
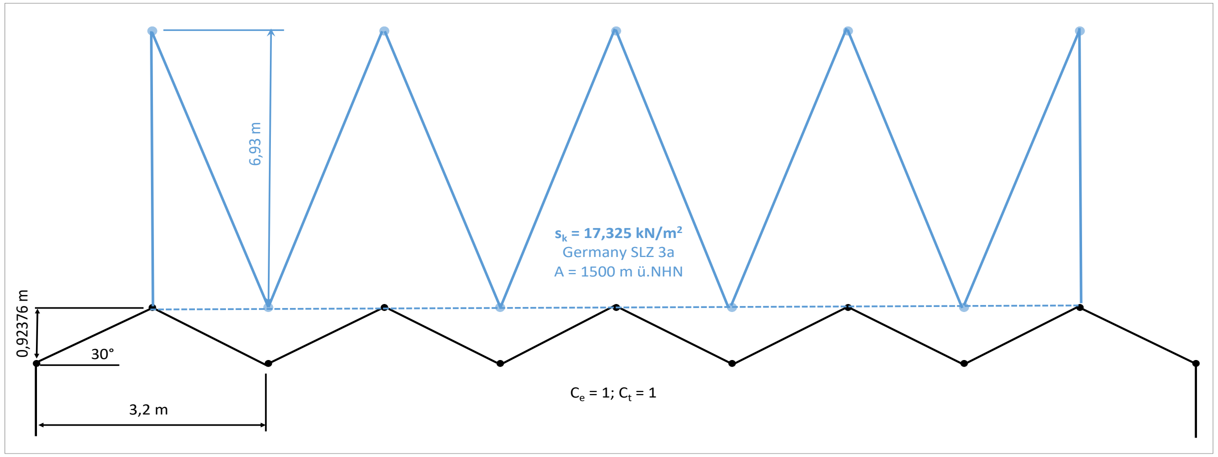
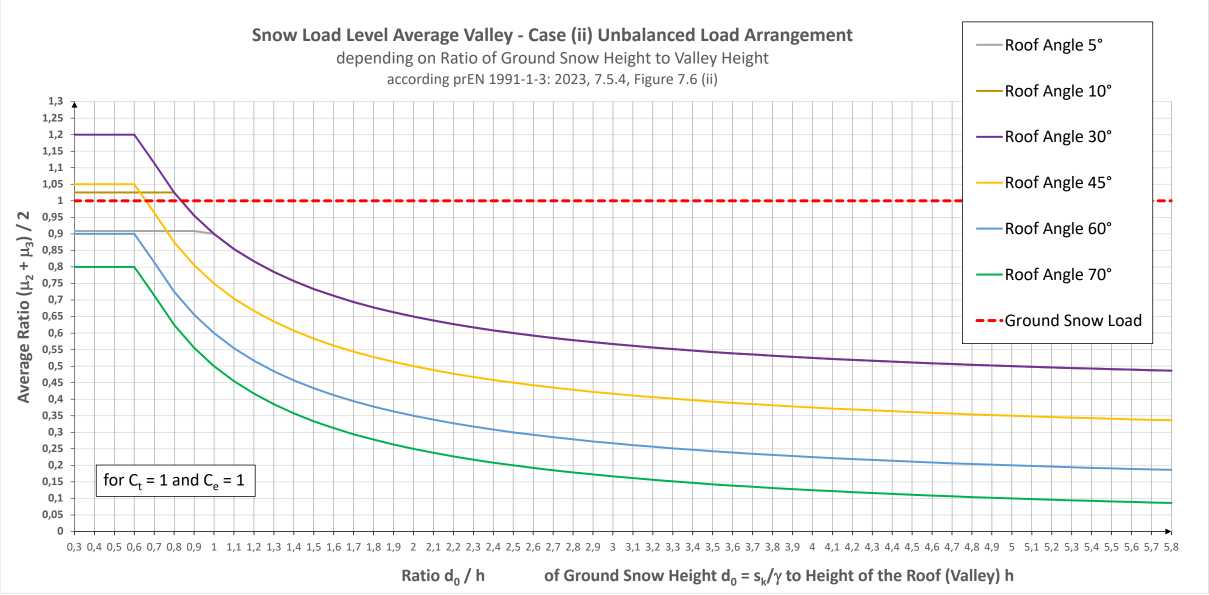


Fig. 1: Shape Coefficient and Snow Load Level FprEN 1991-1-3: 2023, 7.5.4, Case (i) - Inconsistence

5 **(ii)**	(2) The unbalanced load arrangement which should be used for multi-span roofs without retention devices is shown in Figure 7.6, case (ii); the snow load shape coefficient $\mu_2 (\alpha, C_e)$ being given by case (i) in Formula (7.7) and μ_3 being given by Formula (7.8): $\mu_3 = 0{,}9 + 0{,}7\ \alpha/30°$ with $\mu_3 \leq \gamma \cdot h / (C_t \cdot s_k) \leq \mu_{3,max}$ where h is the height of the valley, as shown in Figure 7.6; γ is the snow weight density, specified in 7.5.2.2(1); α is $(\alpha_1 + \alpha_2)/2$. NOTE 1 The values of the snow load shape coefficients for the outer pitches apply when the snow is not prevented from sliding off the roof. NOTE 2 $\mu_{3,max}$ is taken as 1,6 unless the National Annex gives a different value.	The “hard” limit at ridge level h for μ_3 ($d = s_3 / \gamma \leq h$) for the maximum snow height in the valley, independently from μ_2 for the snow above the ridges, can lead to large mounts above the ridges, in case the snow height s_2 / γ is much larger than the height of the valley, see **Fig. 2**.  **Fig. 2**: Roof Snow Load Distribution (snow depts on a Multi-span Roof in the Bavarian Alps)  **Fig. 3**: Ratio of Roof to Ground Snow Load depending on the Snow Load (too large for small snow loads, too small for large snow loads - reliability?	*Note:* *The model cannot be corrected for the shape coefficient μ_3 in the valley alone or by applying more limits. The shape coefficient for the ridge μ_2 needs to be changed depending on μ_3. The volume of the valley needs to be calculated!!!* *The model should be revised. In the consistent proposal the “hard” limit and the “soft” limit at 1,6 will be replaced by a test required for the estimation of the snow load distribution (case 1 or 2):* Case 1: $d_1 \leq h$ *triangular distribution* Case 2: $d_1 > h$ *triangular + rectangular distribution* with: $d_1 = (1{,}6\ h \cdot C_t \cdot C_{e,T} \cdot s_k/\gamma)^{1/2}$

A distribution as in **Fig. 2** does not agree with the wind field above multi-span roofs, which tends to level out any snow surface above the ridges, as on a flat roof. Also, measurements (**Ottawa, 1971**) as well as the tests in **the Climatic Wind Channel Jules Verne, Nantes, France** are evidence against such a distribution.

On the other hand, the total snow load in the valley $S_T = \Sigma\, s_i / (C_t \cdot s_k) = (\mu_2 + \mu_3)/2$ will be reduced with an increasing ratio of ground snow height s_k/γ to valley height h, see **Fig. 3**. For 30°, for a ratio of 5, the total roof snow load will be down to 50% of the ground snow load. Such trends are not acceptable.

The model according to FprEN 1991-1-3: 2023 fails for large snow loads.

For small snow loads, where the "hard" limit cannot be reached, despite the "soft" limit at $\mu_{3,max} = 1{,}6$, the total snow load in the valley can become too large. The trends are shown in **Fig.4**.

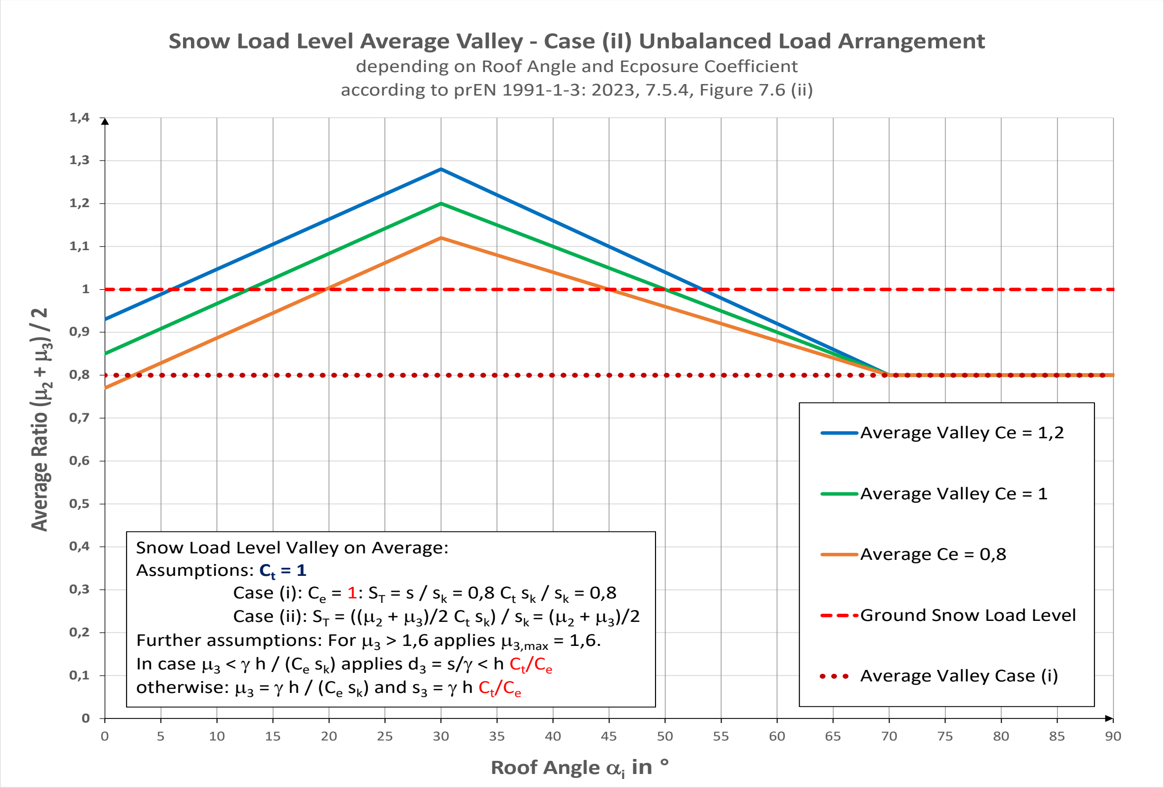


Fig. 4: Ratio of Roof to Ground Snow Load in the Valley depending on C_e and α

Further calculation see Proposal of Figure 6 and Table 4.

Note: Table 4 contains 3 methods for calculation, with s_{min} and s_{max} (directly or with the parametrs) and with shape coefficients μ_2 and μ_3. The direct calculation is the most simple (fool-proof), the calculation with shape coefficients the most elaborate (prone to printing mistakes).

In the consistent proposal the special exposure coefficient $C_{e,T}$ can be chosen to accommodate local drift losses as well as local drift surcharges in the valley.

$C_{e,T} = 1{,}25$ *would lead to the ground snow load level (no drift losses). Such values were measured in the first windward valley in* **Ottawa 1971**. *But in the second valley* $C_{e,T} = 0{,}9$ *was measured. For the overall*

		For a symmetrical valley with $\alpha_1 = \alpha_2 = 30^\circ$; with **$C_e = 1,2$** and **$C_t = 1,2$** results: Shape coefficient above ridge: $\mu_{2,b}(\alpha, C_e) = 0,8\ C_e = 0,96$ Shape coefficient above the internal gutter: $\mu_3 = 0,9 + 0,7\alpha/30^\circ \leq 1,6 = \mu_{3,max}$ With $\mu_3 = 1,6$, the total snow load in the valley (average) is: $S_T = 1,2 \cdot (0,96 + 1,6) / 2 = 1,536$ as a ratio of the ground snow level. For $C_e = 1$ a total snow level of $S_T = 1,2 \cdot (0,8 + 1,6) / 2 = 1,44$ would result. For exposed, windy conditions with $C_e = 0,8$, the total snow load level $S_T = 1,2\ (0,64 + 1,6) / 2 = 1,344$ would be the smallest, but well above ground snow level ($S_T = 1$). The influence of the exposure coefficient C_e (see **Fig. 4**) is opposite to the trend, that one might expect. Also, the total snow load levels for around 30° pitch angle are far above the ground snow load level and particularly unacceptable for very large roofs with many spans as in the greenhouse industry. **The model according to FprEN 1991-1-3: 2023 fails for small snow loads for the most common roof angles around 30°.** The model according to **FprEN 1991-1-3: 2023**, 7.5.4 has not been calibrated with the measurement data (**Ottawa, 1971**) or the tests in the **Climatic Wind Channel Jules Verne, Nantes, France**, where the total snow loads remained below the ground snow load level in all cases, see **Table 2 and 3**. *Solution, principles:* The proposed consistent model for small and large snow loads and small and large valleys is based on **ISO 4355: 2013, B.3**. However, the formulae and limits are corrected and adapted to the EN-format. The redistribution of snow loads into a **confined space** and the differentiation of cases, to be considered, is precedented by the Eurocode itself (see FprEN 1991-1-3; 2023, 7.5.2.2 Flat roofs with parallel rows of tilted solar panels). *Note:* Because roof surfaces are not differentiated in the Eurocode, all types (rough, smooth, slippery, cold and warm) need to be considered. For load case (i) usually cold and rough surfaces keep the largest snow load on the roof. However, for load case (ii) sliding / drifting, a smooth or slippery cladding gives the maximum load in the valley (see case 1 in Fig. 6).	*structure the exposure coefficient was* **$C_e = 0,75$** *- windier than in Europe.* **$C_{e,T} = (1,25 + C_e)/2$** *would limit the drift losses to two out of four sides of the roof. This value agrees well with in-situ measurements for roofs with many valleys. It is also applied for ASCE 7.* *Is a large drift surcharge anticipated (for countries using traditionally "exceptional" snow load distributions),* **$C_{e,T} = 1,5$** *can be chosen nationally, leading to 120% of the ground snow load level, as in* **EN 1991-1-3: 2010, Annex B.** *However, this snow load level cannot be sustained in more than one valley. This fact should be clarified too.*

Background and history of this regulation:

The model for multi-span roofs in **FprEN 1991-1-3: 2023**, 7.5.4 is based on the 1st generation **ISO 4355: 1981**: 5.2.2, which has been withdrawn long ago. Exposure and thermal coefficients C_e or C_t did not exist then. The roof snow load format was simple $s = \mu \cdot s_0$ (with $s_0 = s_k$ and $\mu = 0{,}8$ for a flat roof, standard conditions). Some European countries are still designing without such differentiations. Therefore, they cannot be bordered by some of the problems with this regulation. Some other countries have only small snow loads and do not care about inconsistencies considered minor. Others think, they can repair their problem with the help of NDP or NCI in the National Annex.

It should not be forgotten that multi-span roofs are designed for 150 years. Designers calculated with snow load distributions long before the Eurocode or any other code of practice existed. The roof snow load was simply redistributed into the valley, triangular, if the snow did fit into the volume, triangular + uniform, if not - Geometry. No discussions, no problems. The problems appeared with the creation of standards, not accommodating practical aspects.

In the 1st generation of the Eurocode, in **EN 1991-1-3: 2010**, **5.3.4, Fig. 5.4**, case (i), the snow load in the inner roof pitch (valley) is reduced as on any other pitched roof and disappears at $\alpha_i = 60°$. Sliding into nowhere. This has been finally corrected in **prEN 1991-1-3: 2023**, but inconsistently, see **Fig. 1**.

For case (ii) in the previous standard, a multi-span roof could be loaded with up to 120% of the ground snow load level in the case of drifting according to **EN 1991-1-3, 5.3.4 (3)** and **Table 5.2**. A “hard” limit for larger roof snow load did not exist. Instead, “solutions for roof angles > 60°” were left to National Regulation. This did not lead very far.

Some countries limited the maximum shape coefficient with $\boldsymbol{\mu_3 \leq \gamma \cdot h/s_k + \mu_1}$. However, such a limit would raise the total snow load level to the flat roof snow load level (μ_1) plus the load from the snow filling the valley. No acceptable solution for roofs with large valley volumes. C_e or C_t are also not considered.

Other countries resorted to exceptional drifts according to **EN 1991-1-3: 2010, B.2 (5)**, where the total snow load level was limited to 100% of the ground snow load. It was also clearly explained, where the redistributed snow loads came from (the catchment area: up to 1,5 time the width of the valley). Also, a “hard” limit with $\boldsymbol{\mu = 2\ h/s_k}$ was introduced. C_e or C_t are not used. Very simple, but not sufficient.

Exceptional drifts are no longer part of this norm. Instead, the multi-span roof is now loaded with up to unrealistic 154% of the ground snow load. In the previous drafts the “hard” limit at ridge height h was still misplaced at $\gamma \cdot h / (\mathbf{C_e} \cdot s_k)$. This has been corrected now with $\gamma \cdot h / (\mathbf{C_t} \cdot s_k)$.

Some of the commented flaws in the model for multi-span roofs are inherited parts of the 1st Eurocode generation. With this review for the 2nd generation, they have not been repaired, but made worse.

This is nothing new. It has been commented on since 2015, see below. The disappearing snow in case (i) has been corrected with the first draft. The inconsistent hard limit has been corrected recently after the ENQ. Some other flaws will follow eventually, maybe during the next review for the 3rd generation of the Eurocode.

Note:

In the greenhouse industry most of the roofs are multi-span roofs with cold-smooth or warm-slippery glass or plastic film cladding. Also, for the mostly used roof type “Venlo”, the valleys are very small in comparison to the snow height. Modern roofs Type Venlo are between 0,6 m and 1,2 m high with valleys between 3,2 m and 4,5 m wide. Not much snow fits in these valleys. Therefore, an elaborate calculation of load case 1 would not be justified. In **EN 13031-1: 2019, Annex C** in load case 1 a simplification is used with a triangular distribution over the whole valley with $\mu_0 = 0$ above the ridges. The shape coefficient μ_2 above the inner gutter depends on the type of cladding and heating, varying between 1,6 for warm roofs and 2 for very cold roofs. For load case 2 drift losses (National Choice) are only allowed for the remaining snow cover above the ridge level. The formulae are different, but represent the same model as suggested for **FprEN 1991-1-3: 2023**.

Sources and Literature for this comment

- ISO 4355: 2013: Bases for design of structures – Determination of snow loads on roofs
- ISO 4355: 1998: Bases for design of structures – Determination of snow loads on roofs
- ISO 4355: 1981: Bases for design of structures – Determination of snow loads on roofs
- Comments to ISO-4355-2013 Part IV: drift / slide model multi-pitched roof - Corrigenda
- ASCE 7-22: Chapter 7: Snow Loads
- ACCE 7-16: Chapter 7: Snow Loads + Discussions and examples
- NBCC 2015: In: Ontario Regulation 88/19: Building Code filed May 2, 2015
- FprEN 1991-1-3: 2023: Eurocode 1 –Actions on structures – Part 1-3: General Actions - Sow Load
- Comments prEN 1991-1-3: 2020, Part III: Multi-pitched roofs.
- EN 13031-1+AC: 2019: Greenhouses - Design and construction - Part 1: Commercial production greenhouses
- EN 1991-3: 2010 + A1: 2015: Eurocode 1 – Actions on structures – Part 1-3: General Actions - Sow Load
- ENV 1991-2-3: 1995: Eurocode 1 – Actions on structures – Part 2-3: General Actions - Sow Load
- Dufresne de Virel, M, Delpech, P., Sacre, C: (2000): Wind tunnel investigations of snow loads on buildings. In: Snow Engineering - Recent Advances and Developments. Proceedings of the 4th International Conference on Snow Engineering, Trondheim, Norway, pp. 171-178.
- Grammou, N., Pertermann, I., Puthli, R. (2019): Snow loads on flat roofs with mounted solar arrays - Research results on wind-induced shape coefficients. In: Steel Construction 12 No. 4 (2019), Ernst & Sohn, Berlin, Germany, pp. 364-371.
- Pertermann, I. & Puthli, R.S. (2021): Background Snow – Part II-2: Snow Load Distribution: Multi-pitched Roofs.
- Pertermann, I, Puthli, R.S. (2023): Snow loads on multi-span roofs - Evaluation of prEN 1991-1-3: 2023-03, 7.5.4. In: Steel Construction 17 (2024), Ernst & Sohn Gmbh, Berlin, Germany.
- Sanpaolesi, L. et al. (199) FINAL REPORT, Scientific Support Activity in the Field of Structural Stabilities of Civil Engineering Works, Snow Loads, Commisiion of the European Community, DG III-D3, *Annex 13: Wind Tunnel Experiments*.
- Tabler, D.R. (2003): Controlling Blowing and Drifting Snow with Snow Fences and Road Design. Final Report, National Cooperative Highway Research Program Transportation Research Board of the National Academies.
- Takeuchi, M. (1980): Vertical profile and horizontal increase of drift-snow transport. In: Journal of Glaciology, Vol. 26, No. 94, pp. 481-492.
- Taylor, D.A. (1980): Roof snow Loads in Canada. In: Canadian Journal of Civil Engineering, Vol. 7, No.1, pp.1 -18.

Test results in the Climate Wind Tunnel Jules Verne, Nantes, France (Final Report, 1999)

- Artificial snow (heavy, cold, no dendrites)
- Model problems due to using the same flow medium as in nature
- Model scale rather 1:1, not 1:10 as claimed
- Model surface material hydrophilic, roof pitches too small - no sliding

Roof surface Pos.	Reference roof length l in cm	Snow height ratio (d_{ref} = 15,5 cm)			Roof surface Pos.		Relevant roof length l in cm	Relevant snow height ratio 0° Wind			Relevant snow height ratio 180° Wind		
		l_{max}/l for Maximum	Maximum d_{max}/d_{ref}	Average d_{ave}/d_{ref}	0°	180°		l_{max}/l	d_{max}/d_{ref}	d_{ave}/d_{ref}	l_{max}/l	d_{max}/d_{ref}	d_{ave}/d_{ref}
V1	33	0,23	0,62	0,53	V1	V6	50	0,31	0,53	0,42	0,88	1,04	0,79
V2	33	1	1,49	0,79	V2	V5	17	0,98	1,16	0,42	0	2,03	0,97
V3	33	0,1	1,54	1,19	V3	V4	50	0,46	1,44	1,13	1	1,7	0,85
V4	33	1	1,92	1,21	V4	V3	17	0,98	1,51	0,89	0	1,36	0,68
V5	33	0	1,92	1,24	V5	V2	50	0,45	1,6	1,28	1	1,36	0,53
V6	33	0,86	1,18	1,01	V6	V1	17	0,9	1,23	0,93	0,07	1,18	0,72
Roof MPS 30° total $\Sigma d_{ave} / \Sigma d_{ref}$				**0,995**	Roof total $\Sigma d_{ave} / \Sigma d_{ref}$			Wind 0°		**0,845**	Wind 180°		**0,757**

Table 2: Measurement results for the symmetrical gable roof model MPS 30° (left-hand side) and shed roof models MPN 30°/60° and MPN 60°/30° (right-hand side)

Conclusions:

Local maxima correlate with larger global drift losses, see model MPN 60°/30° (180°-Wind against the steeper pitch) with d_{max}/d_{ref} = 2,03 versus $\Sigma d_{ave} / \Sigma d_{ref}$ = **0,757**. This was also found out in the research on flat roofs with elevated PV systems.

The shape coefficients from the tests (2,03; 1,92 > 1,6) are NOT used for standardization (for good reasons). They seemed too large.

But the total snow load levels (0,995; 0,845 and 0,757) below the reference snow load level were disregarded. The standardized values S_T are even larger, as shown.

The total snow loads remain in all three cases below the reference (ground) snow load level. The symmetrical roof with 30° roof angles reaches the maximum with $\Sigma d_{ave} / \Sigma d_{ref}$ = **0,995**. It offers the least resistance to the wind. The snow loads on single roof pitches increase 100%.

This is where the conviction stems from, on a 30° multi-span roof 120% of the ground snow level would accumulate. As can be seen here, during the drift process this is only sustained in one valley of the roof (V4 + V5), not in two or the roof in total.

The question not asked was, why the snow accumulations in the second valley were greater than in the first valley on the windward side, as in the measurements in Ottawa in 1971.

Measurement results Ottawa 1971 “Blizzard of the Century” by Taylor (1980)

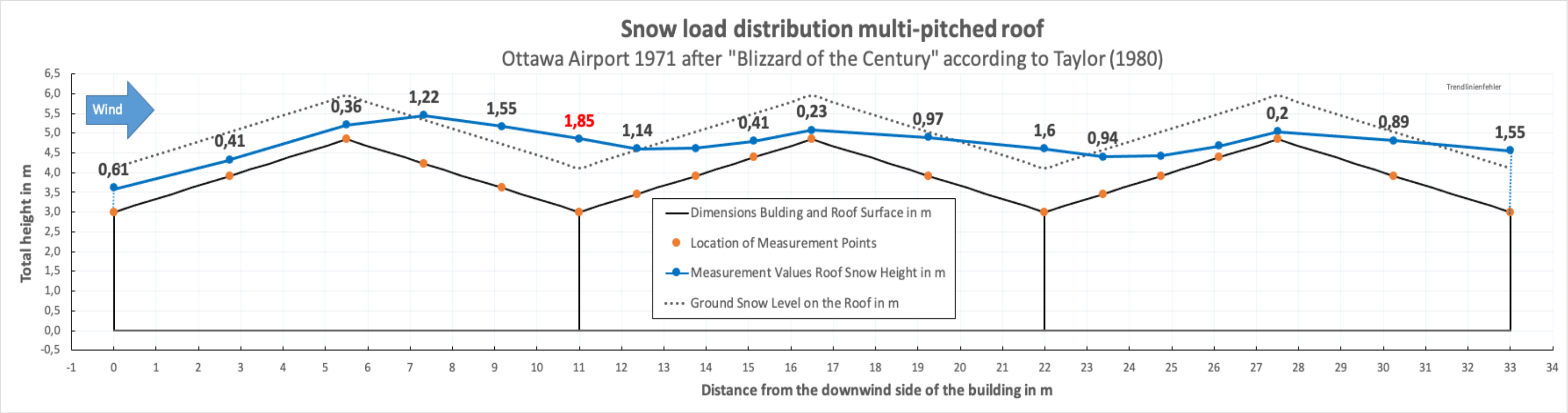


Fig. 5: Roof snow load distribution (snow height in m) in comparison to the ground snow heights on a multi-span roof Ottawa 1971 according to **Taylor (1980)**

Location / Area	**Measured Ratio of Roof Snow to Ground Snow Load of 3 kN/m^2**					
Roof pitch No. 1 - 6	0,414	1,196	0,644	0,873	0,5597	0,817
Outer pitch No. 1 and 6 / Valley No. 1 - 2	0,414	**0,9198**		0,716		0,817
Roof span No. 1 - 3	**0,805**		0,758		0,688	
Total roof	Measured Ratio of Roof Snow to Ground Snow Load: **0,75**					

Table 3: Measured roof snow on a cold multi-span roof with a low roof angle (18,4°) in Ottawa after the “Blizzard of the century” March 1971

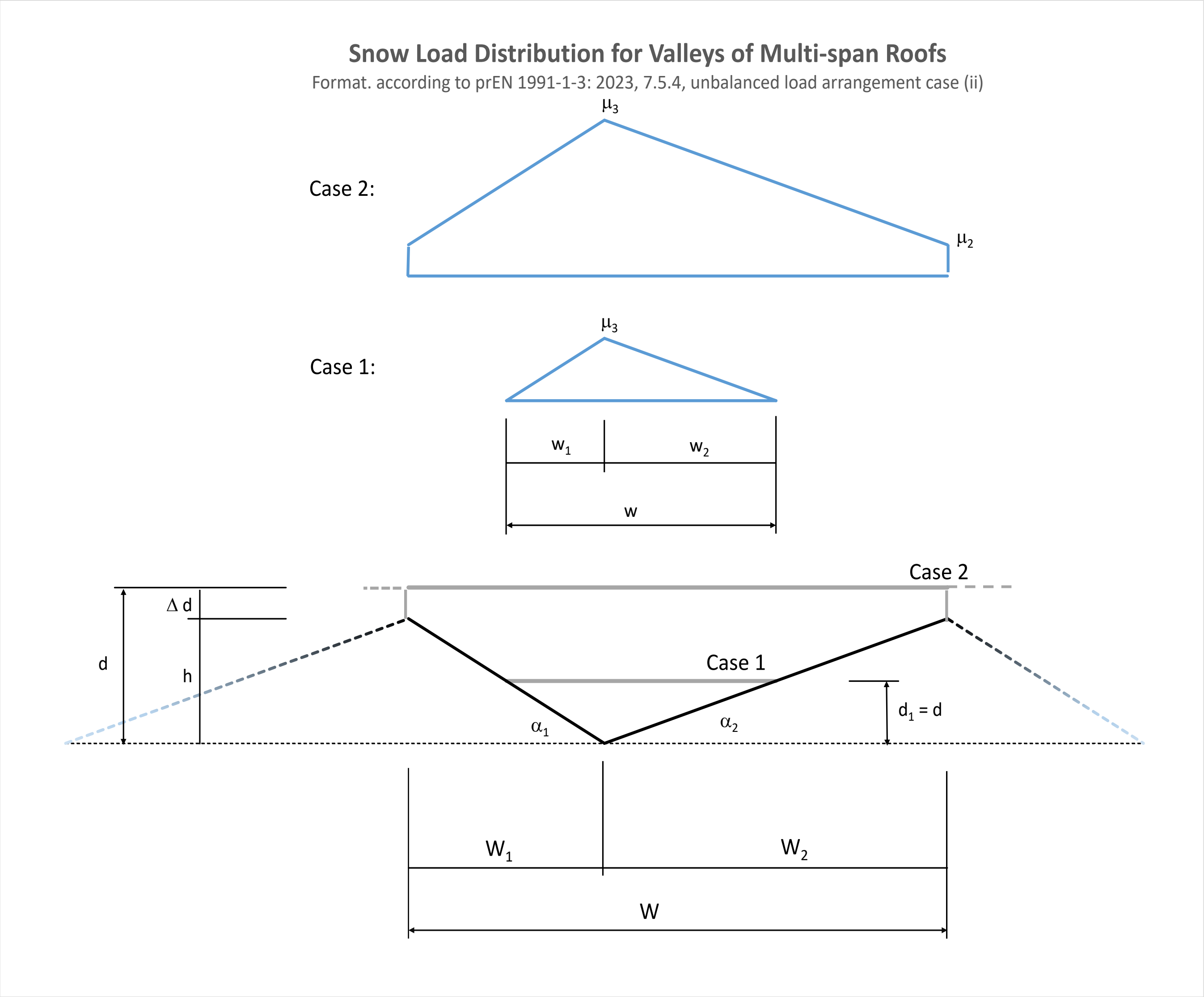
“The multi-span roof had 3 spans of 11 m each and a roof height of 1,83 m between eaves and ridges. The eaves height was small with 3 m above ground. The roof angle of this building was also very low with 18,4°, giving a ridges height of 4,83 m. With these dimensions the building remained within the ground snow drift zone of up to 5 m according to **Tabler (2003)**.” More details and comparisons can be found in **Pertermann & Puthli (2023)**.

“The rather exposed airport location may also have provided fetch distances of 150 m to 300 m to develop a saturated drift flow **(Takeuchi (1980))**. The blizzard lasted for 3 days. The snow load measured 3 kN/m^2 at the end. Therefore, the drift conditions (wind, snow, duration) were extreme for roofs of normal buildings.”

“It is important to understand, that the snow was not “redistributed” by wind after it accumulated, as often claimed, the drifting snow settled there at the first place due to the prevailing wind field saturated with drifting snow. More snow settled down in areas with lower wind speed, changing the wind field in such a way, that the wind could flow with less resistance over the obstacle. **Drifting is a self-regulatory process**.”

Proposal for FprEN 1991-1-3: 2023, 7.5.4, case (ii) – Multis-span roofs

according to Pertermann & Puthli (2023): Snow loads on multi-span roofs



Snow Load Distribution for Valleys of Multi-span Roofs

Format. according to prEN 1991-1-3: 2023, 7.5.4, unbalanced load arrangement case (ii)

Fig. 6: Snow Load Distribution Multi-Span Roof: Unbalanced Snow Load Arrangement for Eurocode - case (ii)

For a **consistent model** for the unbalanced **Load Case (ii)** for large and small valleys and for large and small snow loads, two cases need to be separated, **Case 1** and **Case 2**. Which case applies can only be found out by checking. For the test, in the first step, it is assumed the snow volume is smaller than the volume of the valley. The snow height of the assumed triangular distribution $d_1 = (1{,}6\ h \cdot C_{eT} \cdot C_t \cdot s_k / \gamma)^{1/2}$ is calculated and compared with the height of the valley h. The further calculation is given in **Table 4**.

Note: The drift potential (surcharge) in the valley can be varied (per NDP) using a special exposure coefficient $C_{e,T} > C_e$. With $C_{e,T} = C_{e,F} = 1{,}25$ the ground snow level can be reached. In case a drift surcharge of 120% is anticipated, $C_{e,T} = 1{,}5$ can be chosen. Allowing drift losses perpendicular to the main wind direction leads to $C_{e,T} = (1{,}25 + C_e)/2$, calibrated to measurement values. However, this a **National Choice,** the same as for flat and saddle roofs (C_e and d).

Table 4: Snow Load Distribution Multi-Span Roof: Unbalanced Snow Load Arrangement for Eurocode - case (ii) - Calculation

Load Case (ii)	**Unbalanced Load Arrangement** (Sliding + Drifting)			
	For the inner valley area: Check: $\mathbf{d_1 < / \geq h}$ **with** $\mathbf{d_1 = (1{,}6\ h \cdot C_{e,T} \cdot C_t \cdot s_k / \gamma)^{1/2}}$			
	$d_1 \leq h$: **Case 1**		$d_1 > h$: **Case 2**	
	$d = d_1$		$d = h + \Delta d$ with: $\mathbf{\Delta d = 0{,}8\ C_e \cdot C_t \cdot s_k/\gamma - h/2 \cdot C_e/C_{e,T}}$	
	$w = w_1 + w_2$ and $w = \mathbf{d \cdot (\cot \alpha_1 + \cot \alpha_2)}$		$w = w_1 + w_2 = W_1 + W_2 = W$	
Above the ridge	$\mathbf{s_{min} = 0}$	$\mu_2 = 0$	$\mathbf{s_{min} = \gamma \cdot \Delta d}$ $s_{min} = 0{,}8\ C_e \cdot C_t \cdot s_k - \gamma \cdot h \cdot ½\ C_e/C_{e,T}$	$\mu_2 = 0{,}8\ C_e\ (1 - \gamma \cdot h/(1{,}6\ C_{e,T} \cdot C_t \cdot s_k))$
Above the gutter	$\mathbf{s_{max} = \gamma \cdot d}$ $s_{max} = (1{,}6\ h \cdot \gamma \cdot C_{e,T} \cdot C_t \cdot s_k)^{1/2}$	$\mu_3 = ((1{,}6\ h \cdot C_{e,T} \cdot \gamma)/(s_k \cdot C_t))^{1/2}$	$\mathbf{s_{max} = \gamma \cdot (h + \Delta d)}$ $s_{max} = 0{,}8\ C_e \cdot C_t \cdot s_k + \gamma \cdot h \cdot (1 - ½\ C_e/C_{e,T})$	$\mu_3 = 0{,}8\ C_e + \gamma \cdot h/(C_t \cdot s_k) \cdot (1 - ½\ C_e/C_{e,T})$
Format	**Roof Snow Load:** $\mathbf{s = s_{min} \ldots s_{max}}$ **or according to FprEN 1991-1-3: 2023:** $\mathbf{s = s_k \cdot C_t \cdot \mu_i}$ with i = 2 and 3			
C_e	exposure coefficient, with $0{,}8 \leq C_e \leq 1{,}2$ (NDP);			
$C_{e,T}$	special exposure coefficient for the valleys of multi-span roofs with drift limitation, with $C_{e,T} = (1{,}25 + C_e)/2$ and $C_{e,T} \geq C_e$ (NDP);			
C_t	thermal coefficient, $C_t > 1$ for actively frozen cold roofs, otherwise $C_t = 1$;			
α_1, α_2	roof angles α in ° for the two roof surfaces of the valley i = 1 und i = 2;			
h	valley height (mean value, usually equal to the roof height) in m;			
W	total horizontal width of the valley in m ($W = W_1 + W_2$);			
d	maximum snow depth in the valley in m;			
d_1	reference snow depth for comparison with h (assumed snow depth in the valley if a triangular distribution is possible);			
Δd	snow depth above the ridge in m in case 2;			
w	horizontal width of the snow-covered area in the valley in m ($w = w_1 + w_2$) in case 1;			
γ	equivalent snow weight density in the valley (NDP; suggested is $\gamma = 2$ kN/m³ for cold roofs, for warm roofs $\gamma = 3{,}5$ kN/m³.)			