

SuPeRBE Training Material

Macro Area of Expertise MAE10:

Risk Assessment At Building Level

Hazard: Extreme Heat (C)

Area of Expertise AE10.1:

Building Element: Roof (C5)

Risk Category: Roof structure (5.1)

Level of competence: 1/2/3



Heatwaves and Urban Overheating

Heatwaves are prolonged periods of extreme heat that strain buildings and human health. Urban areas are particularly vulnerable due to the heat island effect and poor thermal comfort in buildings.

What makes it worse?

- Dark surfaces
- Lack of vegetation
- Poor buildings insulation or ventilation
- Urban heat island effect

What can we do?

- Shading
- Natural ventilation
- Green roofs and trees
- Reflective materials and thermal insulation





Heatwaves and Building Overheating

Roof structure

What makes it worse?



- Roofs receive the highest solar radiation of all building elements, especially flat and poorly oriented roofs.
- Lightweight roof structures heat up quickly and transfer heat indoors with little delay.
- Dark roof finishes absorb more solar energy, increasing surface temperatures and heat flux into the building.
- Roof constructions that store heat but cannot effectively release it at night prolong indoor overheating.

What can we do better?



- Improve thermal wave damping and attenuation
- Integrate well-designed green roof systems
- Increase thermal inertia of the roof
- Support passive cooling and safe night ventilation
- Reduce solar heat gains at the roof surface
- Ensure sufficient and continuous insulation



Heatwaves and Building Overheating

Roof structure

Exposure - driven by how much solar heat the roof absorbs and passes indoors (roof colour/SRI, insulation, shading, geometry, rooftop equipment). Dark, unshaded roofs raise surface temperatures and indoor heat gains.

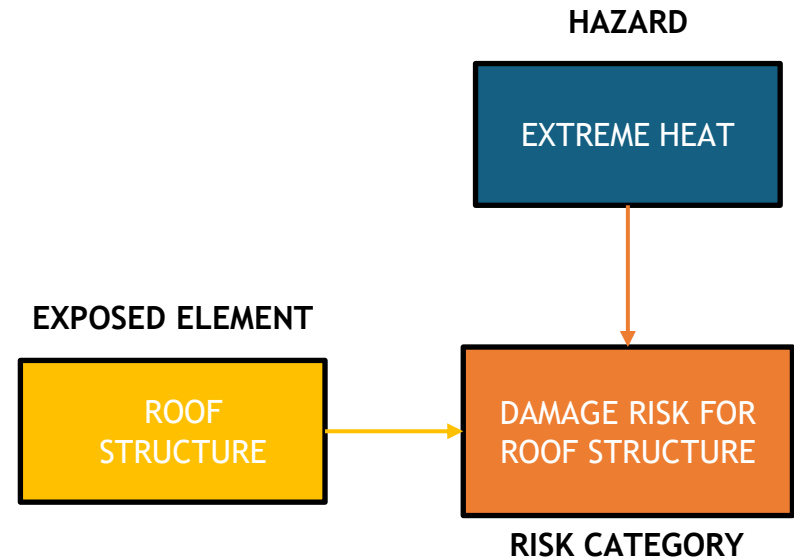
Vulnerability - how the roof system (covering, insulation, structure, airtightness, thermal bridges and ventilation layers) controls heat transfer and heat storage, and whether it can maintain acceptable indoor comfort during prolonged heatwaves. This includes the risk of overheating in top-floor spaces, poor detailing, accumulation of heat in heavy roof build-ups, limited night-time heat release.

Adaptation measures - focus on reducing solar heat gains and heat transfer through the roof by using high-reflectance / high-SRI surfaces, adequate and continuous insulation with minimized thermal bridges, ventilated or cold roof build-ups where appropriate, shading of roof surfaces, penetrations to avoid thermal and moisture weaknesses, and enabling safe night-time heat discharge to limit heat accumulation during heatwaves.



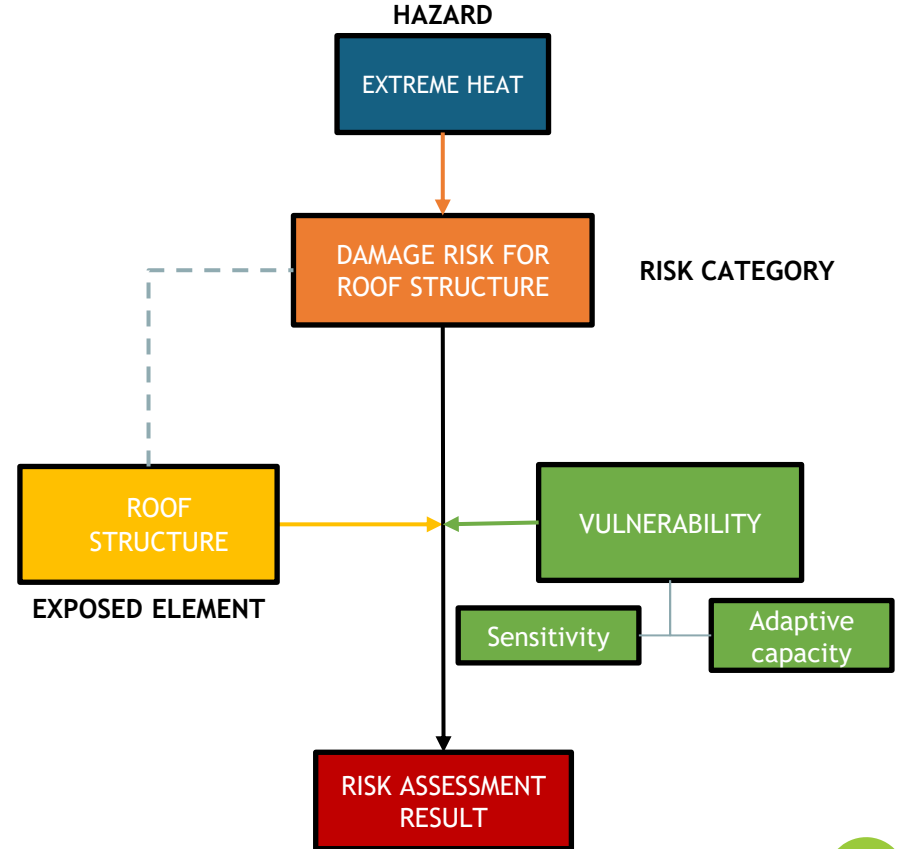
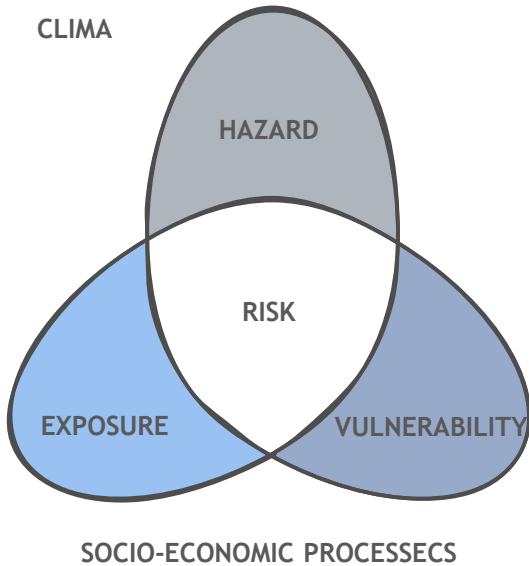
RISK ASSESSMENT FOR DAMAGE RISK ROOF STRUCTURE

- **Hazard:**
Extreme heat
- **Exposed element:**
Roof structure



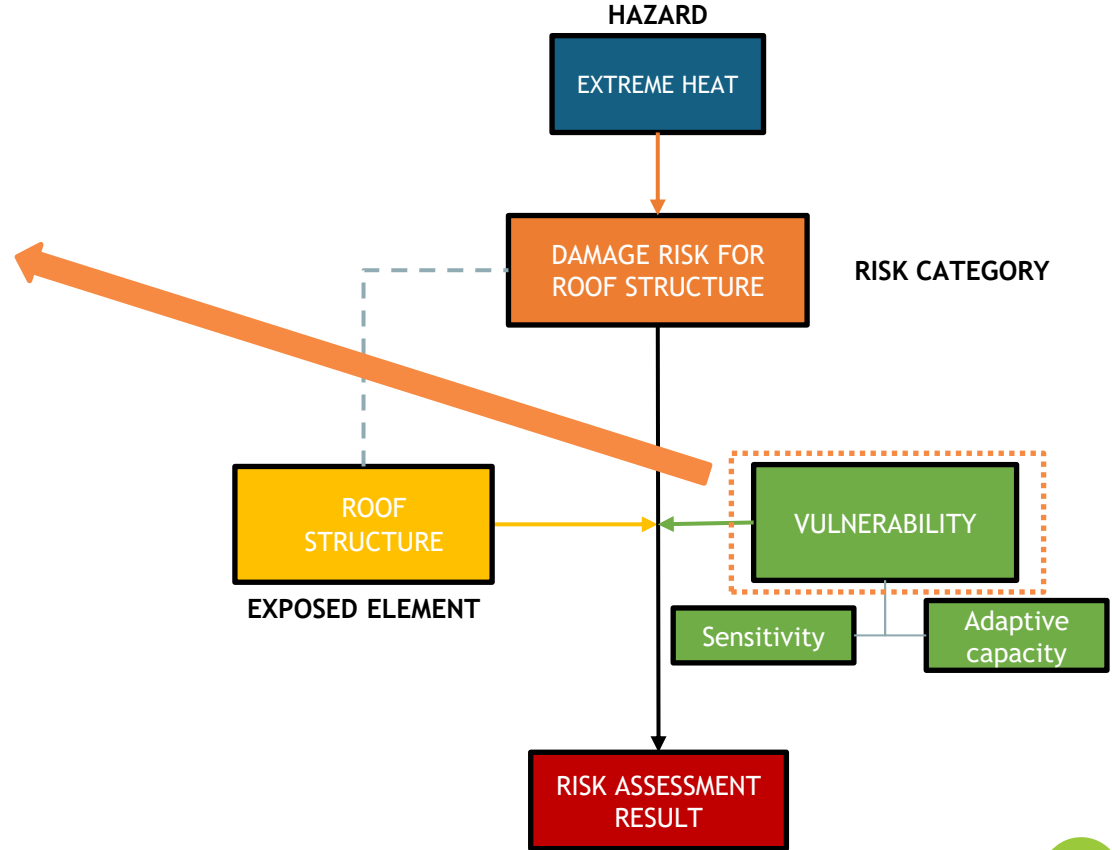


IMPACT CHAIN





C5.1 ROOF STRUCTURE	INDICATOR
C5.1.1 Thermal inertia of roof	Delay between the peak outdoor temperature (or heat flux) and the corresponding peak on the indoor side of the element.
C5.1.2 Thermal wave damping and attenuation of walls	Periodic thermal transmittance (Y)
C5.1.3 Extensive or Intensive Green Roofs	Green roof coverage expressed as the percentage of the total roof area covered by functional green roof systems.



C5.1.1 THERMAL INERTIA OF ROOF

Description:

Using an hourly dynamic simulation with the project weather file, time series are exported for the roof's exterior surface temperature (or heat flux) and the corresponding interior surface response. The thermal inertia is expressed as the number of hours by which the indoor-side peak occurs after the outdoor peak, determined either by comparing the peak times directly or by using cross-correlation to find the best time shift between the two signals.

Objective:

This criterion aims to quantify the roof's thermal inertia by measuring the time lag, in hours, between the peak outdoor temperature (or exterior heat flux) and the corresponding peak response on the indoor side of the roof element.

Relevance:

A higher time lag indicates that the roof can delay and attenuate external heat gains, which helps reduce overheating risk, improve summer thermal comfort, and potentially lower cooling demand by shifting peak indoor loads to cooler hours.



C5.1.1 THERMAL INTERIA OF ROOF

Indicator:

Delay between the peak outdoor temperature (or heat flux) and the corresponding peak on the indoor side of the element.

Benchmarks: HIB

Critical value (1): 8 hours

Optimal value (0): 20 hours

Formula:

$$I = T_{\max_in} - T_{\max_out}$$

$T_{\min_in}$ = Time of maximal indoor roof surface temperature

$T_{\max_out}$ = Time of maximal outdoor roof surface temperature

C5.1.1 THERMAL INTERIA OF ROOF

CALCULATION STEP-BY-STEP

Step 1 - Define roof construction

Collect building plans, construction details, and material properties from data sheets or manufacturer information.

Step 2 - Set up the simulation model

Use a dynamic building energy simulation tool capable of hourly transient analysis and apply the project weather file.

Step 3 - Run the simulation

Run hourly transient simulation. Simulate at least one representative hot period to capture daily thermal cycles of the roof. Extract data for outdoor roof surface temperature (or heat flux) and indoor surface temperature (or heat flux).

Step 4 - Evaluate the simulation

Determine the time (hour) at which the maximum outdoor value occurs and the time of the corresponding indoor peak. Compute the difference between outdoor and indoor peak times, expressed in hours.

Step 5 - Assign criterion value

Compare the resulting time lag with RBtool thresholds to determine the performance level of the roof.

C5.1.1 THERMAL INTERIA OF ROOF

CALCULATION STEP-BY-STEP

EXAMPLE

Outdoor roof surface temperature		
time	T [°C]	notes
12:00	47,1	
13:00	51,8	
14:00	55,6	
15:00	57,2	peak
16:00	56,4	
17:00	54,0	
18:00	52,0	
19:00	51,5	
20:00	50,3	
21:00	49,8	

Indoor roof surface temperature		
time	T [°C]	notes
12:00	27,0	
13:00	27,2	
14:00	27,7	
15:00	28,0	
16:00	28,4	
17:00	29,0	
18:00	29,5	
19:00	30,3	peak
20:00	29,9	
21:00	29,6	

$$I = T_{\max_in} - T_{\max_out}$$

$$I = 15 - 19 = 4 \text{ hours}$$

Formula:

$$I = T_{\max_in} - T_{\max_out}$$

$T_{\min_in}$ = Time of maximal indoor roof surface temperature

$T_{\max_out}$ = Time of maximal outdoor roof surface temperature

Benchmarks: LIB

Critical value (1): 8 hours

Optimal value (0): 20 hours

C5.1.2 THERMAL WAVE DAMPING AND ATTENUATION OF WALLS

Description:

This criterion describes how well external walls attenuate and delay the transfer of periodic heat from the outdoor environment to the indoor space. It uses the periodic thermal transmittance Y (in W/m^2K) to express the dynamic heat flow through the wall under daily cyclic temperature conditions, calculated in accordance with EN ISO 13786.

Objective:

The objective of the criterion is to evaluate the dynamic thermal behavior of wall assemblies by quantifying how effectively their thermal mass and insulation reduce and delay the thermal wave reaching the indoor side. In this way, the criterion captures performance that is not reflected by the steady-state U-value and focuses instead on behavior relevant to daily overheating cycles.

Relevance:

The thermal wave damping capacity of walls is highly relevant for preventing indoor overheating and improving thermal comfort during hot periods and heatwaves. Walls with low periodic thermal transmittance limit daytime heat gains, smooth indoor temperature fluctuations, and postpone heat transfer to the interior, thereby supporting passive cooling and increasing resilience in situations where mechanical cooling is limited or unavailable.

C5.1.2 THERMAL WAVE DAMPING AND ATTENUATION OF WALLS

Indicator:

Periodic thermal transmittance (Y)

Benchmarks: LIB

Critical value (1): 0,05

Optimal value (0): 0,36

Calculation:

Specialized calculation process according EN ISO 13786.

C5.1.3 EXTENSIVE OR INTENSIVE GREEN ROOFS

Description:

This criterion assesses whether extensive or intensive green roof systems are implemented on the building and how much of the roof area they cover, as a measure to reduce roof surface temperatures and indoor heat gains.

Objective:

The objective is to quantify the percentage of the total roof area covered by compliant green roof systems (substrate depth, vegetation type, and accessibility for maintenance).

Relevance:

Well-developed green roofs reduce the risk of overheating by cooling the roof through shading and evapotranspiration, while also improving microclimate resilience during heatwaves. They additionally provide co-benefits through stormwater retention and support for urban biodiversity.



C5.1.3 EXTENSIVE OR INTENSIVE GREEN ROOFS

Indicator:

Green roof coverage expressed as the percentage of the total roof area covered by functional green roof systems.

Benchmarks : HIB

Critical value (1): $\leq 30\%$

Optimal value (0): $\geq 70\%$

Calculation:

$$I = (A_{\text{greenroof}} / A_{\text{total}}) \times 100\%$$

$A_{\text{greenroof}}$ = roof area covered by functional green roof systems (m²)

A_{total} = total roof area (m²)

C5.1.3 EXTENSIVE OR INTENSIVE GREEN ROOFS

CALCULATION STEP-BY-STEP

Step 1 - Gather all required input data

Collect available data about the roof (size, materials, surfaces, quality of maintenance)

Data sources:

- as-built drawing or landscape design documentation
- on-site verification
- Maintenance guide

Step 2 - Identify vegetated areas

Identify all extensive or intensive green roof systems and their total area.

Step 3 - Calculate the indicator

Compute the proportion of green roof systems by dividing the sum of all green roof system areas by the total roof size.

Formula:

$$I = (A_{\text{greenroof}} / A_{\text{total}}) \times 100\%$$

$A_{\text{greenroof}}$ = roof area covered by functional green roof systems (m²)

A_{total} = total roof area (m²)

Benchmarks : HIB

Critical value (1): $\leq 30\%$

Optimal value (0): $\geq 70\%$

C5.1.3 EXTENSIVE OR INTENSIVE GREEN ROOFS

CALCULATION STEP-BY-STEP

EXAMPLE

Roof Type	Area (m ²)
Intensive green roof	98
Extensive green roof	32
Non-green roof	56
Total roof area	186

$$A_{\text{greenroof}} = (98+32) = 130 \text{ m}^2$$

$$A_{\text{total}} = 186 \text{ m}^2$$

$$\rightarrow I = (130 / 186) \times 100 = 69,9\%$$

Formula:

$$I = (A_{\text{greenroof}} / A_{\text{total}}) \times 100\%$$

$A_{\text{greenroof}}$ = roof area covered by functional green roof systems (m²)

A_{total} = total roof area (m²)

Benchmarks : HIB

Critical value (1): $\leq 30\%$

Optimal value (0): $\geq 70\%$

HAZARD LIKELIHOOD

Hazardous event		Slow-on set process		Hazard Value (HV)
Frequent	Likely to occur often in a life time (every 10 years)	Very likely	Very likely to occur in the next 10 years	1 - 0,9
Probable	Likely to occur several times in a lifetime (every 25 years)	Likely	Likely to occur in the next 10 years	0,89 - 0,66
Occasional	Likely to occur some times in a lifetime (every 50 years)	As likely as not	As likely as not to occur in the next 10 years	0,65 - 0,33
Remote	Unlikely but still possible to occur in a lifetime (every 100 years)	Unlikely	Unlikely to occur in the next 10 years	0,32 - 0

Hazard Value (HV) = This information is provided by SECAPs or by experts' judgment

For example, Hazard Value (HV) = **0.8 (Probable)**

NORMALISATION

Once all indicator values for the selected criterion are calculated, normalization converts them to a common 0-1 scale. This ensures each indicator contributes proportionately to the overall resilience score, regardless of its original unit. Normalization enables meaningful data synthesis, cross-context benchmarking, and more transparent, objective decision-making in resilience assessments.

NORMALISATION INTERVAL

Normalisation values	Description
0.0-0.2	Optimal (no improvement necessary)
>0.2-0.4	Rather positive
>0.4-0.6	Neutral
>0.6-0.8	Rather negative
>0.8-1.0	Critical (could lead to severe consequences)

NORMALISATION

HIGHER IS BETTER = HIB

-Normalisation of quantitative indicators' values

For the “higher is better” indicators (higher the numerical value of the indicator, the higher the performance level), the value is normalised applying the following formula:

Where:

X_i : value of the indicator

X_{min} = critical indicator's value (corresponding to score 1)

X_{max} = optimal indicator's value (corresponding to score 0)

Indicator values worse than X_{min} will be allocated to the value X_{min} and indicator values exceeding X_{max} will be allocated to the value X_{max} .

$$X_{norm} = \frac{x_{max} - x_i}{x_{max} - x_{min}}$$

NORMALISATION

LOWER IS BETTER = LIB

-Normalisation of quantitative indicators' values

For the “lower is better” indicators (lower the numerical value of the indicator, the higher the performance level.), the value is normalised applying the following formula:

Where:

x_i : value of the indicator

x_{min} = optimal indicator's value (corresponding to score 0)

x_{max} = critical indicator's value (corresponding to score 1)

Indicator values below x_{min} will be allocated to the value x_{min} and indicator values exceeding x_{max} will be allocated to the value x_{max} .

$$X_{norm} = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

NORMALISATION

EXAMPLE

For C5.1.3 EXTENSIVE OR INTENSIVE GREEN ROOFS
with an indicator value of 69,9%:

$$X_{norm} = \frac{x_{max} - x_i}{x_{max} - x_{min}}$$

Where:

Higer is better (HIB)

$x_i = 69,9 \%$

Optimal value = $x_{max} = 70\%$

Critical value = $x_{min} = 30\%$

$X_{norm} = (70 - 69,9) / (70 - 30) = 0,0025$ (This means the building envelope is performing optimal).

NORMALISATION INTERVAL

Normalisation values	Description
0.0-0.2	Optimal (no improvement necessary)
>0.2-0.4	Rather positive
>0.4-0.6	Neutral
>0.6-0.8	Rather negative
>0.8-1.0	Critical (could lead to severe consequences)

OVERALL VULNERABILITY (VULNERABILITY VALUE - VV)

CRITERION	Normalised value	Weight
C5.1.1 THERMAL INTERIA OF ROOF	1	0,35
C5.1.2 THERMAL WAVE DAMPING AND ATTENUATION OF WALLS	0,6	0,3
C5.1.3 EXTENSIVE OR INTENSIVE GREEN ROOFS	0,0025	0,35

Normalised score Weight

$$VV = \sum_{i=1}^n (I_i \times W_i)$$

$$VV = 1 \times 0,35 + 0,6 \times 0,30 + 0,0025 \times 0,35 = 0,53$$

Vulnerability Value (VV) = 0,53

Vulnerability Level =
NEUTRAL PERFORMANCE