

SuPeRBE Training Material

Macro Area of Expertise MAE10:

Risk Assessment At Building Scale

Hazard: Storms (E)

Area of Expertise MAE10.5:

Building Component: Façade (E4)

Risk Category: Damage risk façade openings (E4.2)

Level of competence: 3



Storms

Windstorms are caused by rapid changes in atmospheric pressure, which are often associated with stronger currents and more dynamic weather systems. Damage caused by summer convective storms and winter cyclonic winds, which damage roofs and trees, is becoming increasingly common.

What makes it worse?

- Unstable atmospheric conditions
- Intense precipitation, hailstorms
- Unsuitable shape/condition of buildings, loose elements

What can we do?

- Aerodynamic shape of the building
- Reinforcement of structures
- Window protection
- Backup power sources, equipment protection





Storms

Façade

Why does it make it worse?



- Storm debris is a major cause of façade and glazing failure during windstorms
- Impact damage leads to glass breakage and loss of façade integrity
- Breached openings allow wind-driven rain and internal pressurisation, escalating damage
- Failed seals and joints compromise watertightness of façade systems
- Secondary debris (ice, roof elements) can further damage façade openings

What can we do better?



- Adapt façade opening design to local storm exposure
- Use performance-based testing to verify impact resistance of glazing and frames
- Strengthen fixings, seals, and façade-opening interfaces to maintain watertightness
- Protect large or exposed glazing with impact-resistant or shielding systems
- Improve façade resilience to prevent progressive envelope failure



Storms

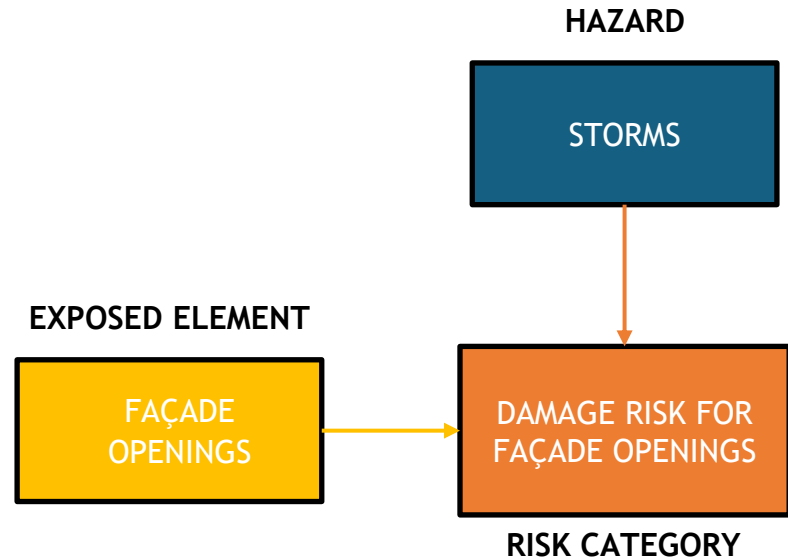
Façade openings

Façade opening design strongly influences a building's exposure and vulnerability to storms and is a key lever for storm adaptation.

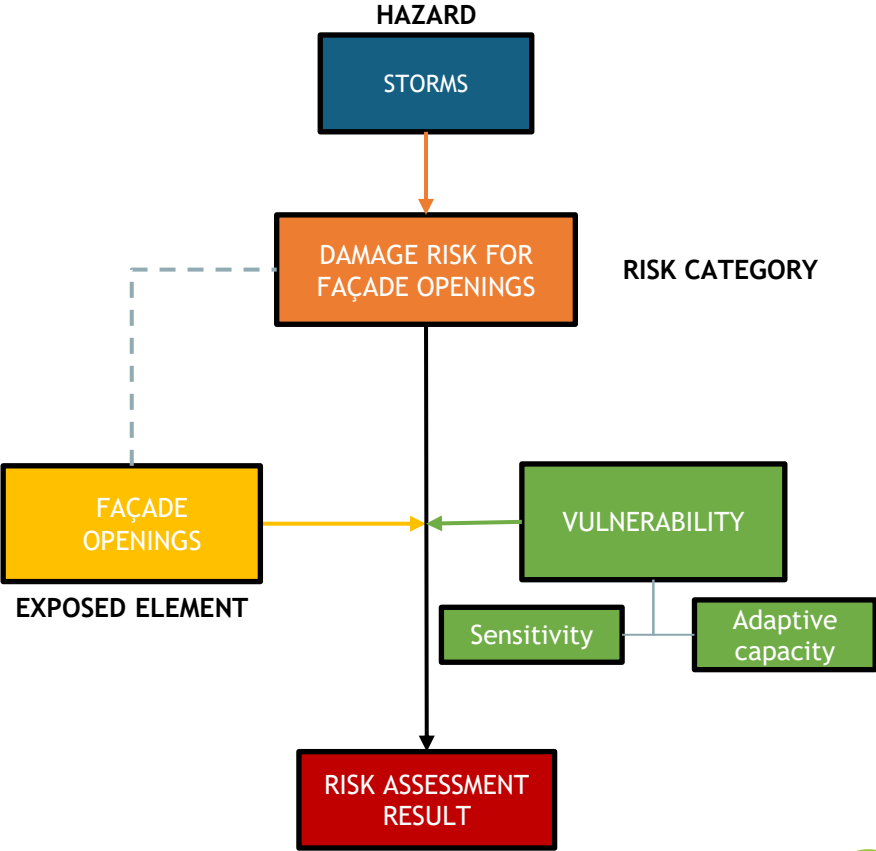
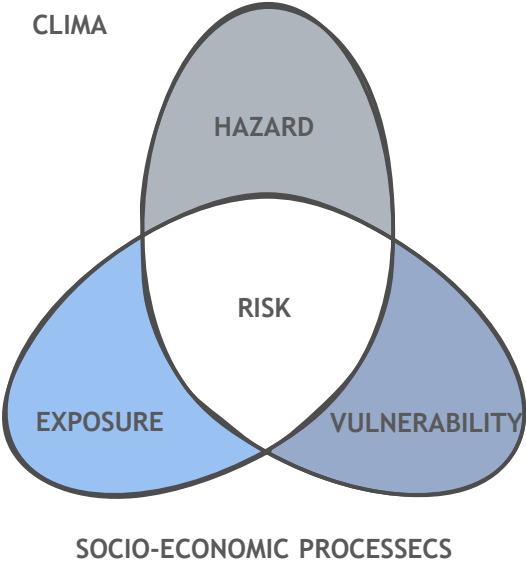
- **Exposure** - how wind pressures and wind-borne debris act on façade openings, influenced by building height, orientation, urban context, size and distribution of glazing, and the likelihood of debris impact from surrounding buildings or rooftop elements
- **Vulnerability** - how windows, glazing, frames, fixings, and sealant joints maintain integrity under wind pressure, debris impact, and wind-driven rain, and whether local failures lead to water ingress, internal pressurisation, and progressive façade or roof damage
- **Adaptation measures** - focus on impact-resistant and performance-tested façade openings, robust fixing and anchorage, resilient seals and interface detailing, protection of large or exposed glazing, and design approaches that limit progressive failure of the building envelope under extreme wind events

RISK ASSESSMENT FOR DAMAGE RISK FOR FAÇADE OPENINGS

- **Hazard:**
Storms
- **Exposed element:**
Façade openings

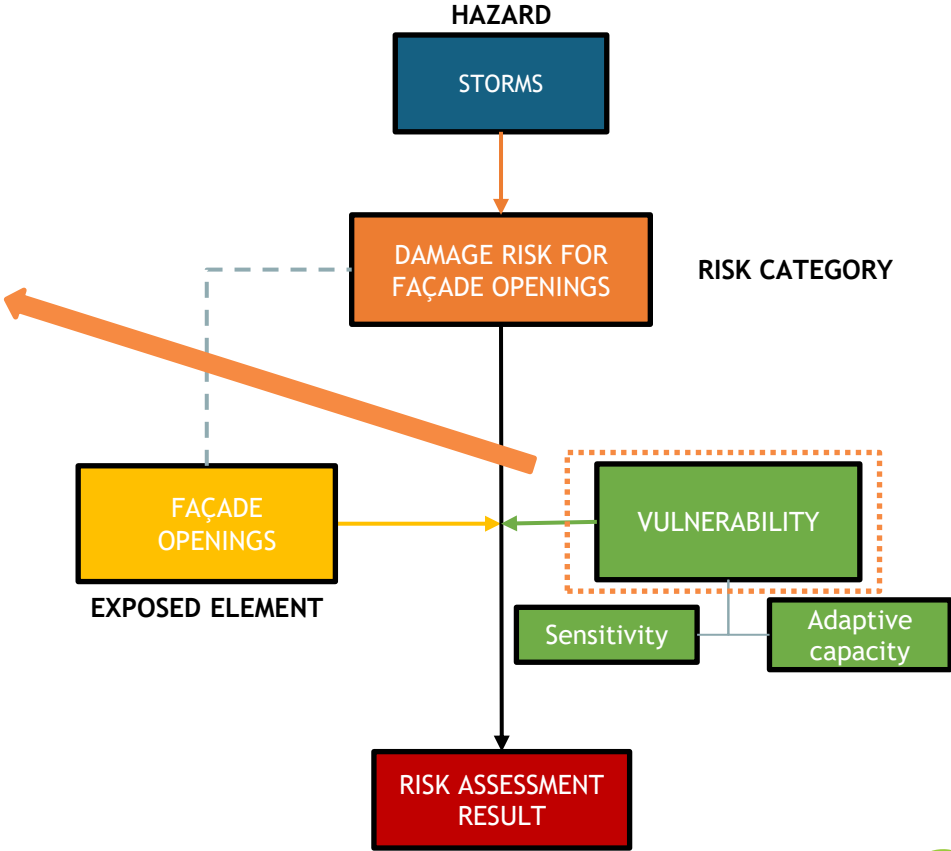


IMPACT CHAIN



CRITERIA

E4.2 FAÇADE OPENINGS	INDICATOR
E4.2.1 Storm-Resilient Openings	Share of large openings that are wind-rated and impact-resistant
E4.2.2 Wind-Resistant Openings	Wind resistance of façade openings
E4.2.3 Shatter Resistance of Glass	Ability of glass to retain fragments after breakage



E4.2.1 STORM-RESILIENT OPENINGS

Description:

This criterion evaluates the share of large openings (e.g., windows, glazed doors, skylights) that are wind-rated and impact-resistant, reducing the risk of failure and damage during storms.

Objective:

To ensure that large façade openings (windows, glazed doors, skylights) are wind-rated and impact-resistant so they can withstand storm pressures and debris strikes without failure, maintaining the building's envelope integrity, safety, and functionality during and after extreme wind events.

Relevance:

Severe storms increase wind pressures and wind-borne debris risks that can shatter unprotected glazing, cause water ingress, and trigger cascading interior damage and downtime. Verifying storm-resilient openings aligned with local wind hazard conditions reduces safety risks, limits damage and operational disruption, and supports continuity of use under storm conditions.

E4.2.1 STORM-RESILIENT OPENINGS

Indicator:

Share of large openings that are certified as wind-rated and impact-resistant (%), based on product certification and inspection.

Benchmarks: HIB

Critical value (1): 0 %

Optimal value (0): 100 %

Calculation:

The indicator is determined as the percentage of large façade openings (windows, glazed doors, skylights) that are documented as both wind-rated and impact-resistant based on product certification, supplier technical data, design documentation, and site inspection records, verified against local wind-hazard conditions. The reported value is the share of certified openings out of all large openings in scope.

E4.2.1 STORM-RESILIENT OPENINGS

CALCULATION STEP-BY-STEP

- Inventory all large openings in scope and assign IDs/locations for traceability.
- Collect certificates, supplier data sheets, design specs/drawings, and inspection records for each opening.
- Verify that certificates cover both wind rating and impact resistance for the installed model/configuration and local wind conditions.
- Confirm installation details (frames/fixings/glazing) match the certified system; mark uncertain cases separately.
- Compute % Storm-Resilient Openings = $(\text{Certified wind-rated \& impact-resistant openings} \div \text{Total large openings}) \times 100$ and report with a list of non-certified items.

E4.2.1 STORM-RESILIENT OPENINGS

Data sources:

- Product certification documents
- Supplier technical data sheets
- Design documentation
- Site inspection records

EXAMPLE

Given the following large openings and documentation status:

Certified wind-rated & impact-resistant: 72 units

Not certified / insufficient evidence: 28 units

$W_{\text{total}} = 100$ units

$$I = (W_{\text{certified}} / W_{\text{total}}) \times 100\%$$

$$I = (72 / 100) \times 100 = 72\%$$

(Performance is moderate; above critical but below optimal.)

E4.2.2 WIND-RESISTANT OPENINGS

Description:

This criterion evaluates the wind resistance of façade openings (windows, doors, skylights) to verify they can withstand design wind pressures during storms without failure, leakage, or detachment, thereby maintaining the integrity of the building envelope.

Objective:

To ensure façade openings (windows, doors, skylights) have sufficient certified wind resistance to withstand storm wind pressures without failure, leakage, or detachment, maintaining envelope integrity and building functionality during extreme wind events.

Relevance:

Increasing storm intensity elevates wind pressures on façades, making inadequately rated openings a pathway for breakage and water ingress that drive costly interior damage and downtime. Verifying wind resistance against local design wind conditions reduces safety risks, limits damage, and supports continuity of use.

E4.2.2 WIND-RESISTANT OPENINGS

Indicator:

Wind resistance of façade openings (kN/m^2), i.e., the certified wind pressure rating that the installed opening systems can resist without failure under local design wind conditions.

Benchmarks: HIB

Critical value (1): $< 1.0 \text{ kN/m}^2$

Optimal value (0): $\geq 2.5 \text{ kN/m}^2$

Calculation:

Determine the certified wind resistance (kN/m^2) of the installed façade openings from product technical data sheets, test certificates, supplier documentation, and design specifications, and verify suitability against local design wind pressures. Where multiple opening types exist, report the governing (lowest) certified rating and confirm that installed details match the certified system.

E4.2.2 WIND-RESISTANT OPENINGS

CALCULATION STEP-BY-STEP

- Inventory all façade openings in scope and register IDs/locations and types (window, glazed door, skylight).
- Collect product technical data sheets, test certificates, supplier documentation, and design specifications for each installed opening type.
- Determine local design wind pressures/parameters for the site and confirm the certificates/test ratings are applicable to those conditions.
- Verify that the installed configuration (frame, glazing, fixings, spans/hardware) matches the certified system so the rating is valid.
- Report the governing certified wind resistance (kN/m^2) across the installed opening types and note any items lacking evidence or not meeting local design wind pressures.

E4.2.2 WIND-RESISTANT OPENINGS

Data sources:

- Product technical data sheets
- Test certificates
- Supplier documentation
- Design specifications
- Local wind hazard data

EXAMPLE

Given the following certified wind resistance by opening type (governing = lowest):

Type A windows: 3.0 kN/m^2 (20 units)

Type B glazed doors: 2.2 kN/m^2 (15 units)

Type C skylights: 1.8 kN/m^2 (5 units)

Governing certified resistance = $\min(3.0, 2.2, 1.8) = 1.8 \text{ kN/m}^2$
(Performance is moderate; above critical $< 1.0 \text{ kN/m}^2$ but below optimal $\geq 2.5 \text{ kN/m}^2$.)

E4.2.3 SHATTER RESISTANCE OF GLASS

Description:

This criterion evaluates the ability of glass in façades and openings to retain fragments after breakage during storms, reducing injury risk and secondary damage from wind-borne debris.

Objective:

To ensure façade glazing is laminated or otherwise treated so that, if broken, fragments are retained and the opening remains safer and more weathertight during storm events.

Relevance:

Storm impacts can shatter unprotected glass, causing hazardous debris, rapid water ingress, and cascading interior damage. Verifying shatter-resistant glazing reduces safety risks, limits damage and downtime, and supports continuity of use under storm conditions.

E4.2.3 SHATTER RESISTANCE OF GLASS

Indicator:

Ability of glass to retain fragments after breakage (qualitative), determined by whether installed glazing is laminated or treated for shatter resistance with supporting certification/testing.

Benchmarks: -

Critical value (1): Standard annealed glass with no fragment retention (high risk of dangerous shattering).

Optimal value (0): Glass is laminated or treated to retain fragments upon breakage, with certification or testing confirming performance.

Calculation:

Review supplier technical data sheets, test certificates, façade design documentation, and site inspection records to confirm that installed glazing is laminated or otherwise treated for shatter resistance and that documentation substantiates fragment retention performance.

E4.2.3 SHATTER RESISTANCE OF GLASS

CALCULATION STEP-BY-STEP

- Inventory all glazed façade/opening types in scope and record IDs/locations and glazing build-ups.
- Collect glass product data sheets, supplier certificates, and test reports for the installed glazing systems.
- Verify that documentation explicitly confirms laminated construction or approved shatter-resistant treatment with fragment retention performance.
- Cross-check drawings/specifications and inspection records to confirm the installed glazing matches the certified build-up.
- Classify each opening as “shatter-resistant (certified)” or “non-shatter-resistant/insufficient evidence,” and report the overall status with a list of gaps for remediation.

E4.2.3 SHATTER RESISTANCE OF GLASS

Data sources:

- Glass product data sheets
- Supplier certificates
- Test reports
- Façade design documentation
- Site inspection records

EXAMPLE

Given the installed glazing inventory and documentation:

Laminated / shatter-resistant glazing (with certificates): 80 units

Standard annealed glass (no fragment retention): 20 units

$G_{\text{total}} = 100$ units

Share of shatter-resistant glazing = $(80 / 100) \times 100 = 80\%$

(Result: Mixed compliance. The presence of non-retentive annealed glass prevents an “optimal” qualitative outcome; list and remediate the 20 non-compliant units.)

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.

EXAMPLE:

For E4.2.1 Storm-Resilient Openings
with an indicator value of 65% wind-rated and impact-resistant openings

Where:

$X_i = 65$

$X_{max} = 100$

$X_{min} = 0$

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

$x_{norm} = (100 - 65) / (100 - 0) = 0,35$ (Rather positive)

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
E4.2.1 Storm-Resilient Openings	0,35	0,20
E4.2.2 Wind-Resistant Openings	0,21	0,15
E4.2.3 Shatter Resistance of Glass	0,35	0,15

Normalised score  Weight 

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

$$VV = 0,35 \times 0,20 + 0,21 \times 0,15 + 0,35 \times 0,15 \\ = 0,15$$

Vulnerability Value (VV) = 0,15

Vulnerability Level =
OptOPTIMAL