9.8 Glass breakage

Glass is a brittle construction material and therefore does not allow for excessive deformations. Exceeding the elasticity border due to mechanical or thermal influences immediately leads to breakage. The defined guidelines referring to this must be followed precisely. For thermal load, the normal float glass used for facades that are partially in the shade, may be exposed to a maximum temperature difference of 40 K (EN 572) to 42 K. If the glass is exposed to temperature changes exceeding this range, then this float glass should be replaced with tempered or heat strengthened glass in order to increase this delta. This is particularly essential in the case of absorbing solar protection glasses.

Another danger that may lead to glass breakage is on the construction site when modern, coated insulating glass packages on racks are unprotected from the sun. The sun heats the glass packs and, due to the coatings, the heat is unable to dissipate. This inevitably results in glass breakage. Therefore, glass packs standing in the open must be covered with opaque material. Also, smallsized insulating glass panes with unfavourably proportioned sides and asymmetric structures need a thinner tempered glass pane to prevent breakage.

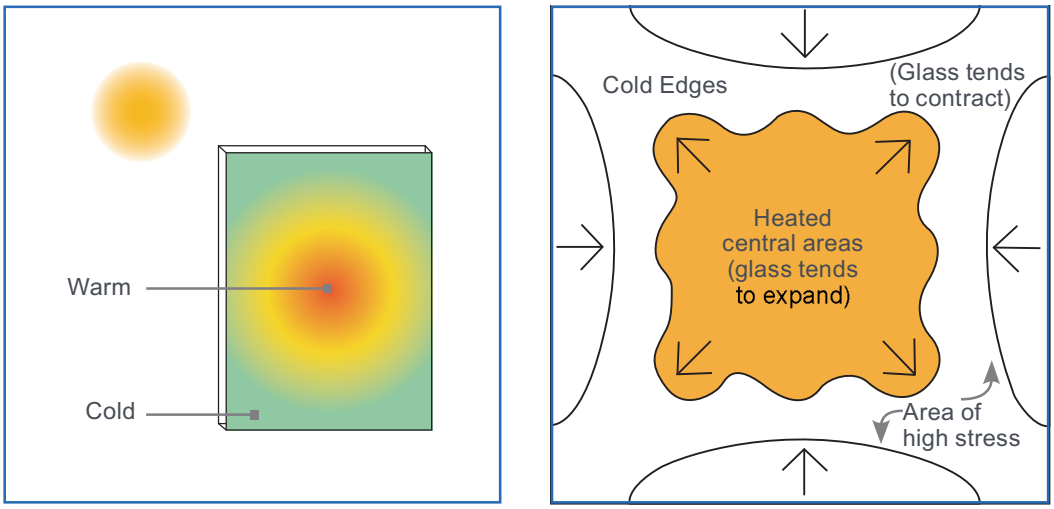
Glass breakage formerly caused by residual stress is practically ruled out, due to today's glass production methods. But both unqualified finishing of edges with nearly invisible micro-cracks and mechanical surface damage may lead to medium-term pane failure. The same applies to incorrect transport and edge damage. In such cases, the failure may not become obvious immediately, but only at a later point in time. Breakage by the material itself can only occur with tempered glass, so-called "spontaneous" breakage occurs where nickel sulphide inclusions are present (→ chapter 7.2).

Generally, it can be said that glass breakage is almost 100 % preventable if glass is handled appropriately with advance planning, correct dimensioning, proper use and maintenance.

9.8.1 Thermal breakage / thermal stress

9.8.1.1 General

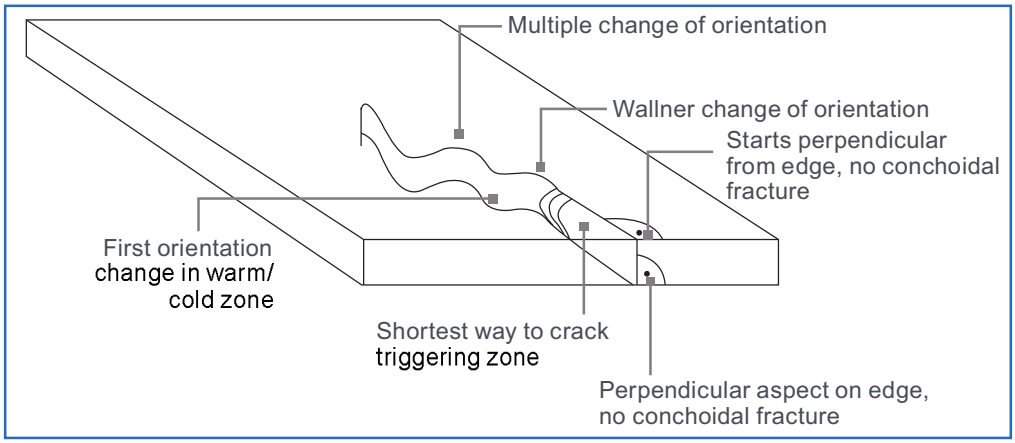
Thermal stress is caused when one area of glass is heated, while another part remains cold at the same time. It is not an issue if the temperature increase is uniform across the entire glass pane. Heated areas are under expansion – cold areas are under compression due to the temperature difference (ΔT) aspect.



9.8.1.2 Thermal cracks

Thermal breakage always starts at the edge and is perpendicular (90°) to the glass edge.

- Different areas expand and contract differently; when they collide, energy seeks its way out towards the nearest edge and breakage starts
- Breakage can be single or multiple depending on thermal stress build up
- It starts straight for 2 to 5 cm and then branches out into one or more directions
- The number of branches or secondary cracks depends on the amount of stress



9.8.1.3 Factors influencing thermal breakage

Thermal stress caused by temperature differences (ΔT) is the only ultimate factor.

ΔT depends on:

- Environmental factors - Façade orientation
  - Solar intensity (W/m²)
  - Temperature difference between inside and outside

- Glass-related factors
  - Glass types and glazing build up (solar energy absorption)
- Architectural factors - Internal and external blinds
  - Ventilation, heating elements
  - Internal constructions, obstacles
  - Window profiles
  - Heavy shadow (surroundings, building shape)

9.8.1.4 Factors influencing glass strength and thermal breakage risk

The glass strength and therefore the risk of thermal breakage depends directly on the edge quality of the glazing.

The following conditions influence the edge quality:

- Cutting
  - tools, oil, speed, type of table when cutting laminated glass, etc.
- Handling / Transportation / Storage
  - usage of separators, avoiding cracks during handling, how glass is tied down
  - clean and proper storage feet
- Project site / Installation
  - protection of glass pack, thermal bridges, clean profiles

9.8.1.5 Calculation and evaluation of the risk of thermal breakages

The French standard NF DTU 39 part 3 is the basis of thermal stress considerations. This standard describes the calculation methods, the influence of environmental and construction conditions, the glass properties and required glass qualities related to maximum allowed temperature differences.

Glass quality	Admissible temperature difference ΔT [K]
Monolith. glass -edge ground	42
End size laminated glass -edge ground	42
Monolith. glass rough cut	35
End size laminated glass rough cut	35
Heat strengthened glass	150
Tempered glass	215
Tempered enamelled glass	150

Table: Max. admissible ΔT and required glass qualities (selection) – more glass types in NF DTU 39

Maximum temperature differences shown in the table are based on the theoretical resistance of a specific glass type supported along all sides. If the conditions vary, appropriate maximum temperature differences should be taken into consideration.

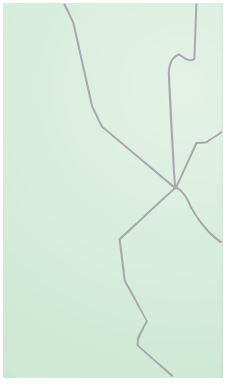
Glass resistance under thermal stress is significantly influenced by the quality of the edge finishing. The maximum allowable values are only valid when edge finishing has no defects (→ chapter 9.8.1.4).

The Guardian Technical Services provides a comprehensive service for the assessment of thermal breakage risk using customer and project-related data.

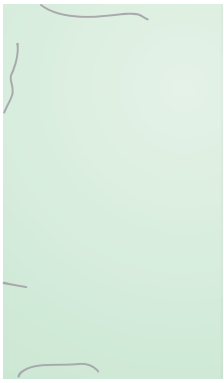
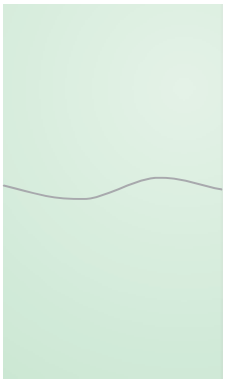
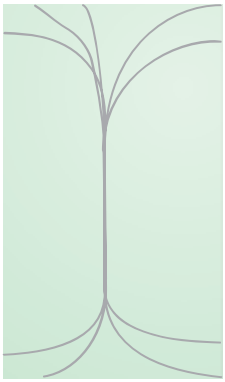
IGU producers and glaziers are responsible for the quality and the installation of glazed units. In case of doubt, Guardian recommends the consideration of a lower maximum allowable temperature difference. The final decision regarding the glazing to be installed is the responsibility of the insulating glass unit manufacturer.

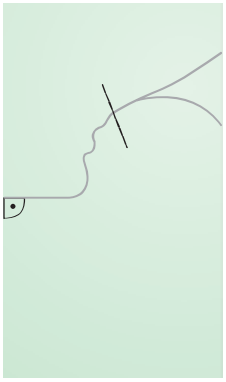
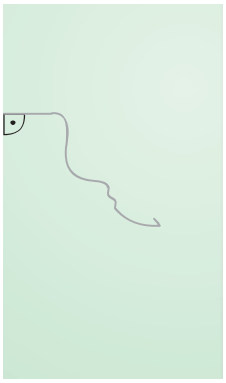
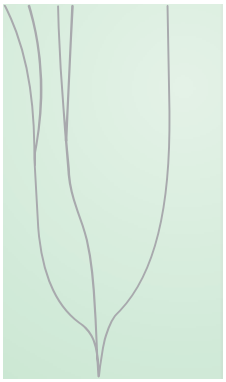
Guardian does not provide any warranty regarding thermal breakage.

9.8.2 Typical glass fracture pattern

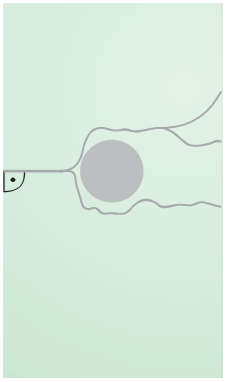
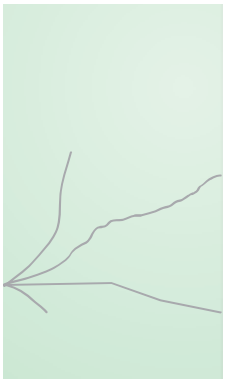
Kind of glass breakage		Representation
Example:	**Edge breakage float glass** Mechanical point load • Short term • Weak to medium intensity Happens with float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass	Pane view  Fracture cross section 
Reason:	Little stones between glass panes, hammer blow on glazing bead, other blow and collision effects	
Characteristics:	Feeding angle all directions, out of square, continuous angle out of square,origin to be seen in the edge area, shells possible in the breakage centre	
Example:	**Edge breakage heat strengthened glass** Mechanical point load • Short term • Weak to medium intensity Happens only with heat strengthened glass per DIN EN 1863	Pane view  Fracture cross section 
Reason:	Little stones between glass panes, hammer blow on glazing bead, other blow and collision effects	
Characteristics:	Feeding angle all directions, out of square, continuous angle out of square, origin to be seen in the edge area, shells to be found often in the breakage centre	

Standards and guidelines

Kind of glass breakage		Representation
Example:	**Clamping crack** Mechanical point or line load • Short term dynamic • Long lasting static Happens with float glass, laminated safety glass, laminated glass, cast resin panes and patterned glass	Pane view  Fracture cross section 
Reason:	Too small or wrong setting blocks and very high glass weight, wrong handling of the block lever, length change (thermal dilatation) of glass/frame not considered	
Characteristics:	Feeding angle all directions, out of square, continuous angle out of square, origin to be seen in the edge area, shells possible in the breakage center	
Example:	**Torsion breakage** Mechanical line load • Short term • Dynamic To be found at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass	Pane view  Fracture cross section 
Reason:	Glass thickness not sufficient, specially when mounted on two sides, twisted and jamming casement frames, movements in the structure with load transfer to the pane	
Characteristics:	Feeding angle all directions, out of square, continuous angle out of square, generally not clearly allocated	
Example:	**Area pressure breakage** Mechanical distributed load • Long lasting • Dynamic/statical To be found at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass	Pane view  Fracture cross section 
Reason:	Too high load of the insulating glass by temperature, air pressure and/or altitude differences between production and installation location, undersized aquarium pane supported on four sides	
Characteristics:	Feeding angle all directions, out of square, no breakage center to be seen, continuous angle rectangular, no shells at glass edge	

Kind of glass breakage		Representation
Example:	**Hybrid crack** Thermal/mechanical loads • Overlapping	Pane view  Fracture cross section 
	To be found at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass	
Reason:	Several effects by area load (squall) on undersized and already thermally loaded pane	
Characteristics:	Feeding pane rectangular, continuous angle out of square, no edge shells, no breakage center to be seen	
Example:	**Thermal normal crack** Thermal line load • Weak to medium intensity	Pane view  Fracture cross section 
	To be found at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass, wired glass may differ due to the network	
Reason:	Partial covering of the pane in the interior during solar irradiation, glazing depth too low, as package stored sound-, heat- and solar protection glazing (especially insulating glass) without protection against direct solar irradiation.	
Characteristics:	Feeding angle rectangular, continuous angle rectangular, edge shells not to be found at incoming	
Example:	**Delta breakage** Mechanical line load • Long lasting • Static/dynamic • Two sides bearing	Pane view  Fracture cross section 
	Happens with float glass, laminated safety glass, laminated glass, ornamental and wired glass	
Reason:	Long-lasting, high snow load on overhead glazing being mounted on two or three sides	
Characteristics:	Feeding angle out of square, continuous angle out of square, no shells on glass edge, breakage center on non mounted edge	

Standards and guidelines

Kind of glass breakage		Representation
Example:	**Thermal line crack** Thermal line load • Weak to strong intensity	Pane view  Fracture cross section 
	To be found at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass, wired glass differs possibly due to wire net work	
Reason:	Partial covering of the glass pane with interior decoration, dark spots (stickers, advertisements) on the glass pane, a large plant leaf or likewise inside directly on the glass pane	
Characteristics:	Feeding angle rectangular, continuous angle rectangular, edge shells not to be found at incoming	
Example:	**Edge joint breakage** Mechanic point load • Short term • Weak to strong intensity	Pane view  Fracture cross section 
	To be found at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass	
Reason:	Placing panes on stone or metal parts, edges hit by metal part, mishandling of tensioning strips of transport racks	
Characteristics:	Feeding angles all directions, out of square, continuous angle out of square, edge shells to be seen at crack in different sizes depending on the power of force effect, very obvious centre seen at the edge	
Example:	**Edge pressure breakage** Mechanical point load • Short term or long term aggressive • Weak to medium intensity	Pane view  Fracture cross section 
	To be seen at float glass, laminated safety glass, laminated glass, cast resin panes and ornamental glass	
Reason:	Undersized blocks for high glass weight, too high clamping pressure by screw connection, too high clamping pressure by using nails for wood strips without preformed tape	
Characteristics:	Feeding angle out of square, continuous angle out of square, shells of edge not or seldom present, origin at edge to be seen	