

SAFETY GLASSES



GLASS UNLIMITED

TOUGHENED AND LAMINATED

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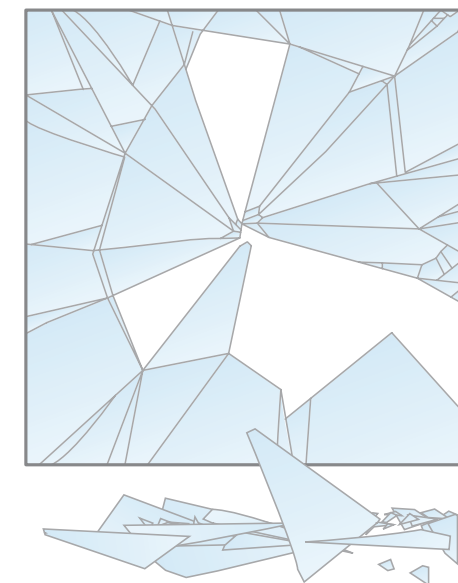
NB

This brochure gives a general overview of the technical characteristics of AGC Flat Glass Europe's toughened and laminated safety glasses. It is the responsibility of users – not of AGC Flat Glass Europe – to satisfy themselves that a particular product is suitable for the proposed application and that the product itself, its application and the standards, regulations and codes of good practice in force in the relevant country or countries are satisfactory.

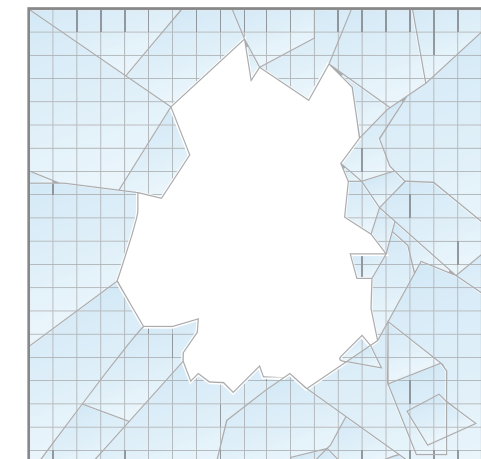
The proposed conditions under which a product is to be used should be verified by AGC Flat Glass Europe, its local representative or a glass specialist. Unless otherwise stipulated in advance and in writing, AGC Flat Glass Europe shall not be liable in any way for consequences arising from the use of a glass as illustrated in the examples in this brochure.

Not all products are available in all countries. For further information, consult your local AGC Flat Glass Europe representative.

Glass is a recurrent feature of modern architecture: clear, reflective, insulating, solar control, coloured, textured ... glass can be processed in many ways to meet architects' and designers' requirements. The wide range available from AGC Flat Glass Europe combines technical and aesthetic features seamlessly. Naturally, safety is an integral consideration. A glass surface should be made secure enough to prevent both burglary and injury, should someone fall on it. This brochure also sets out the various safety requirements. There is a product and safety solution for every scenario. This brochure is designed to be an informative aid to anyone wishing to check the application of standards, safety classes and technical solutions in respect of a particular range. Be it laminated or toughened glass, AGC Flat Glass Europe has unrivalled expertise from which we would like both industrial players and those in the glass sector to benefit.



Float fragmentation



Safety glass fragmentation

This brochure supplements document 'Stratobel®/Stratophone®' and comprises the following:

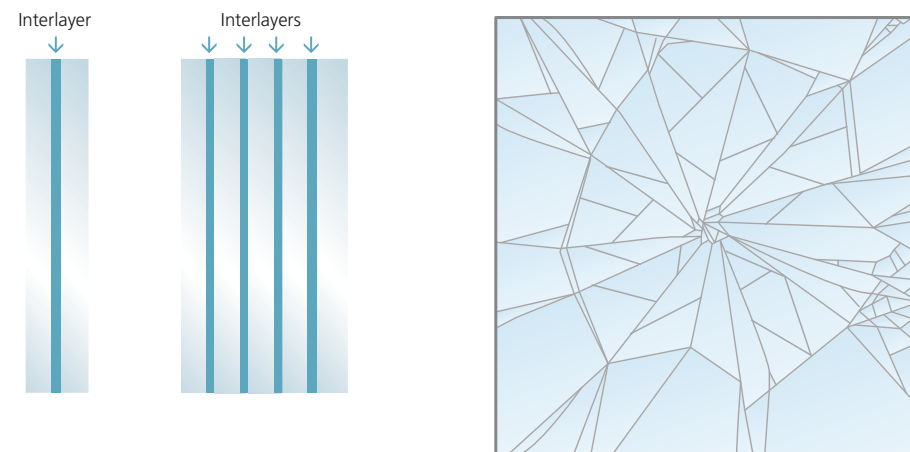
- an overview of laminated and toughened glasses;
- a description of the various standards and tests used to classify safety glass and the corresponding AGC ranges;
- some examples of safety-glass applications.

2. LAMINATED GLASS

2.1. Description

A laminated glass is an assembly comprising at least two panes of glass bonded together across their entire surface by one or more interlayers. For laminated safety glasses, the most widely used interlayer is a PVB (polyvinyl butyral) film. In the event of breakage, the bond between the glass and the interlayer ensures that the broken pieces of glass remain in place (at least for a certain time or up to a specified load level).

In some cases, polycarbonate sheets may also be included.



Break pattern of laminated glass

AGC has two ranges of laminated glass:

- Stratobel: laminated safety glass
- Stratophone: acoustic laminated safety glass

2.2. System

Laminated glasses with PVB interlayers have their own system to denote composition. This takes the form of two (or more) figures indicating the thickness of the different panes of glass in mm, followed by a further figure separated from the rest by a dot giving the number (rather than the thickness) of the PVB films between each pane of glass. The PVB films are 0.38 mm thick.

Example: A glazing denoted as 66.2 has two panes of (float) glass measuring 6 mm separated by two PVB films each 0.38 mm thick; some countries also describe laminated glass by giving its total thickness, namely 12.76 in the case of 66.2.

2.3. Use

Depending on its composition, thickness, number of components, number of PVB films and other factors, various levels of protection are available to meet requirements in terms of:

- protecting individuals against the risk of injury by:
 - pieces of sharp, broken glass;
 - falling (defenestration);
- protecting goods and safety against burglary and vandalism of private homes, shops and offices; in this context the glazing should remain in place and prevent anyone or anything penetrating it;
- protection against firearms;
- protection against explosions.

In addition to providing protection in the broad sense, laminated glass is also the only solution for applications such as floors, steps, lift shafts, balustrades and so forth.



2.4. Certification

Stratobel and Stratophone laminated glasses comply with standards EN ISO 12543 and are considered laminated safety glasses under standard EN ISO 12543-2. They are CE-marked in accordance with standard EN 14449.

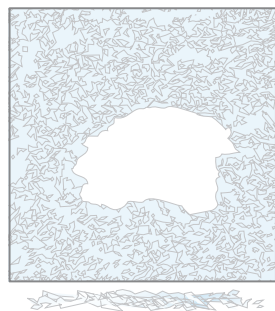
3. THERMALLY TOUGHENED GLASS

3.1. Description

Thermally toughened glass¹ (so-called as opposed to annealed glass) is a glass which has been treated to increase its resistance. The glass may also undergo what is known as 'heat-soak' treatment after toughening. We recommend heat-soaking for all toughened glasses measuring 6 mm and above and which are likely to experience regular temperature changes.

The characteristics of thermally toughened glasses are fundamentally different from those of the base products from which they are manufactured:

- they cannot be cut, sawn, perforated or processed after toughening since the toughening process causes significant stress on the glass; all cutting, holes and any edge treatment must therefore be performed before toughening.
- they have much higher levels of mechanical strength and impact resistance; characteristic resistance via bending of thermally toughened glass is 120 N/mm² as compared with 45 N/mm² for annealed glass.
- they have a higher level of resistance to thermal shock: they can resist differences in temperature of approximately 200°C while in annealed glass, breakage can occur under temperature differences of approximately 30°C; however, this value can vary considerably and depends on the quality of the edge processing among other factors.
- in the event of breakage, they fragment into blunt pieces which are smaller than annealed glass, thereby limiting the risk of injury; thermally toughened glass is therefore only considered as a safety glass where protection against injury from sharp fragments is required.



Break pattern of toughened glass

3.2. Use

Since it breaks into blunt pieces, thermally toughened glass is perfectly suited to all applications where the aim is to prevent injury from sharp splinters of glass in the event of breakage; for example in bus shelters, telephone boxes, shower screens and so forth.

3.3. Certification

Thermally toughened glass complies with standard EN 12150. Thermally toughened and heat-soak treated glass complies with standard EN 14179. They are CE-marked in accordance with these standards.

4. EUROPEAN CLASSIFICATION STANDARDS

In order to classify and distinguish the performance of various products, new EN European standards have been published by the European Committee for Standardisation (CEN).

These standards are gradually replacing the former national standards such as NBN in Belgium and NF in France (which are now becoming obsolete) and are being recognised as national standards in themselves. As a result, following publication, European standard EN 12543 on laminated glass is now referred to as standard NBN EN 12543 in Belgium, NF EN 12543 in France and so forth. In reality, the text adopted is exactly the same in the various countries.

NB: In this brochure, standards are referred to solely by the prefix 'EN' rather than 'NBN EN' or 'NF EN'; the documents are exactly the same, though.

In terms of safety glass, four test and classification standards have been published:

- EN 12600: Glass in building - Pendulum test – Impact test method and classification for flat glass (2002)
- EN 356: Glass in building - Security glazing – Testing and classification of resistance against manual attack (1999)
- EN 1063: Glass in building - Security glazing – Testing and classification of resistance against bullet attack (1999)
- EN 13541: Glass in building - Testing and classification of resistance against explosion pressure (2000).

The four standards are described briefly on the following pages. Details are also given of the corresponding AGC product ranges.

Use of glass products

To make appropriate use of glass products, the following three points should be borne in mind:

- 1) The European standards mentioned only set out a product's class; they never stipulate how to use a product within a specific project. The choice as to the most suitable glass product to use is one for the national authorities and each country may publish its own rules, which must be observed.
- 2) In all cases, the thicknesses corresponding to a particular class are merely the minimum applicable according to the test carried out; the actual thicknesses to be used should be determined on a case-by-case basis depending on the size of the glass, the stresses upon it and the installation method to be used.
- 3) In all cases, using safety glass is only a viable option if the accompanying joinery provides the same level of resistance since it is naturally the weakest component of a unit which will determine the level of resistance of the assembly as a whole. Test and classification standards are also available for joinery and are similar to those for glass.

5. EN 12600 – IMPACT RESISTANCE

Test principle

Standard EN 12600 'Pendulum test – Impact test method and classification for flat glass' details the classification of glasses according to impact by soft material. The test detailed uses a twin-tyre impactor and is used to classify glass products in terms of risk of injury and defenestration.



Pendulum test EN 12600

The classification makes a distinction between the fall height and the type of breakage.

Fall height:	Type of breakage:
1: 1200 mm	A: cracks with separated fragments (annealed, heat-strengthened, chemically toughened)
2: 450 mm	B: cracks with combined fragments (laminated, wired, film on annealed glass)
3: 190 mm	C: disintegration into small particles (thermally toughened)

Performance classification of a glass product is expressed as follows using two figures and one letter: α (β) ϕ where:

- α is the highest class of drop height during which the glass either breaks or does not break in accordance with one of the two breakage patterns described below;
- β is the type of breakage;
- ϕ is the highest class of drop height during which the glass either breaks or does not break without allowing penetration (in accordance with the first of the two criteria listed below); where a glass breaks at the lowest fall height allowing penetration, it is demoted as 0.

The two fragmentation methods accepted by the standard for criteria α are:

- Numerous cracks appear but no shear or opening is allowed within the test piece through which a 76-mm diameter sphere can pass when a maximum force of 25 N is applied
- Disintegration occurs and the 10 largest crack-free particles collected and weighed altogether within three minutes after impact shall weigh no more than a mass equivalent to 6,500 mm² of the original test piece.



Pendulum test EN 12600

Examples

- A laminated glass is classed as **1B1** if it resists an impact from a fall height of **1200 mm** without allowing penetration.
- A laminated glass is classed as **2B2** if it resists an impact from a fall height of **450 mm** without allowing penetration.
- A thermally toughened glass is classed as **1C1** if it resists an impact from a fall height of **1,200 mm** without breaking.

AGC range – Toughened glass

Toughened and toughened heat-soaked glasses meet the criteria set out in standard EN 12600.

Range toughened glass

Class	Composition	Weight (kg/m ²)
1C3	4	10.0
1C3	5	12.5
1C2	6	15.0
1C2	8	20.0
1C1	10	25.0
1C1	12	30.0
1C1	15	37.5
1C1	19	47.5

This classification applies to all toughenable glasses (Planibel, Stopsol, Sunergy, Stopray T, etc.) with the exception of Colorbel enamelled and Artlite silk-screen printed glasses, in respect of which no classification is required.

AGC range – Laminated glass

Stratobel laminated safety glasses and Stratophone acoustic laminated safety glasses are classified as follows in line with standard EN 12600.

Range Stratobel - Stratophone

Class	Composition	Thickness (mm)	Weight (kg/m ²)
2B2	33.1	6	15.0
2B2	44.1	8	20.0
1B1	55.1	10	25.0
1B1	66.1	12	30.0
1B1	33.2	7	16.0
1B1	44.2	9	21.0
1B1	55.2	11	26.0
1B1	66.2	13	31.0

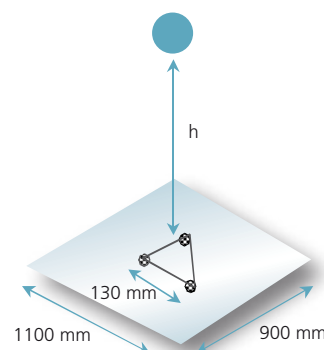
Notes:

- Thickness compositions in excess of 66.2 (i.e. 88.2,) also meet the criteria for class 1B1.
- In some specific cases (sports halls, psychiatric hospitals, etc.), laminated glass with strengthened or toughened components may be appropriate. This product is called Stratobel Super.
- Stratophone acoustic laminated safety glass performs to the same level as Stratobel laminated glass when impacted.

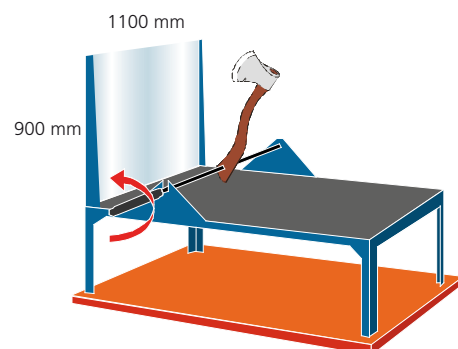
6. EN 356 – BURGLAR RESISTANCE

Test principle

Standard EN 356 «Security glazing – Testing and classification of resistance against manual attack» sets out the testing methods to be used to classify glasses in terms of their resistance to burglary. There are eight classes of increasing resistance; the first five classes denoted P1A to P5A are based on the falling ball test using a metal ball weighing 4.1 kg; the next three classes denoted P6B to P8B are based on an axe test.



Ball test EN 356



Axe test EN 356

In falling-ball tests, a test sheet measuring 1,100 mm x 900 mm is positioned horizontally and is impacted by a ball weighing 4.1 kg in a triangular area in the centre of the glass (13 cm between impacts). The number of impacts and the drop height vary depending on the class.

Classification of resistance against vandalism, burglary and theft

Test	Class	Test description
Ball	P1A	3 impacts by a ball falling from 1,500 mm
	P2A	3 impacts by a ball falling from 3,000 mm
	P3A	3 impacts by a ball falling from 6,000 mm
	P4A	3 impacts by a ball falling from 9,000 mm
	P5A	3x3 impacts by a ball falling from 9,000 mm
Axe	P6B	30 to 50 blows by a hammer and an axe
	P7B	51 to 70 blows by a hammer and an axe
	P8B	> 70 blows by a hammer and an axe

The ball test is considered successful if the ball does not pass through the test sheet entirely within five seconds of the moment of impact.

In the axe test, a test sheet measuring 1,100 mm x 900 mm is positioned vertically. First the different test-sheet glasses are broken using hammer blows (minimum of 12). Next, axe blows are used to try to make a hole in the centre of the glass.

The axe test is considered successful if the area (400 mm x 400 mm) subject to the axe blow does not become completely detached from the rest of the test sheet.

AGC range

AGC has a range of Stratobel (and Stratophone) glasses which meet the criteria for the different classes within standard EN 356.

Range Stratobel and Stratophone

Class	Product	Composition	Thickness (mm)	Weight (kg/m ²)
P1A - P2A	Stratobel 701-1	33.2	7	16
P1A - P2A	Stratobel 901-2	44.2	9	21
P3A - P4A	Stratobel 801-1	33.4	8	17
P3A - P4A	Stratobel 002-1	44.4	10	22
P5A	Stratobel 002-1	44.6	10	22
P5A	Stratobel 402-3	66.6	14	33
P6B	Stratobel 502-1	multi-laminated	15	33
P6B	Stratobel 505-2	bi-laminated	15	33
P6B	Stratobel 802-2	multi-laminated	18	43
P7B	Stratobel 303-3	multi-laminated	23	53
P8B	Stratobel 504-4	multi-laminated	35	81
P8B	Stratobel 803-5	multi-laminated	28	64
P8B	Stratobel 905-8	multi-laminated	49	114

NB: For safety reasons, high-performance compositions are coded.

A Stratobel PC range of laminated glasses incorporating polycarbonate components is also available; these glasses are thinner and lighter but provide the same level of performance.

Range Stratobel PC (Polycarbonate)

Class	Product	Thickness (mm)	Weight (kg/m ²)
P6B	Stratobel PC 214.541	15	28
P7B	Stratobel PC 216.541	17	30
P8B	Stratobel PC 219.841	20	34

7. EN 1063 – BULLET RESISTANCE

Test principle

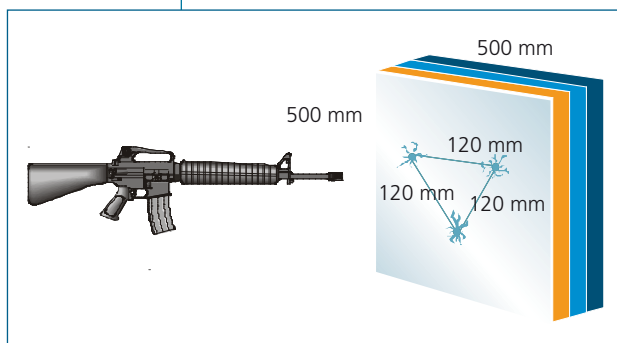
Standard EN 1063 «Security glazing – Testing and classification of resistance against bullet attack» describes the methods to be used to classify bullet-resistant glass.

The standard makes a distinction between resistance against two types of weapon: handguns and rifles (BR classes) and shotguns (SG classes).

There are nine classes. For each category of weapon tested, the glass is classed as bullet-resistant if it stops all the bullets on the three sheets tested. The report also states whether or not there are any splinters – (S) or (NS) – behind the glazing.

Classes BR1 to BR7 contain glasses offering increasing levels of protection. This means that a glass meeting the requirements stipulated for a given class also meet those of the classes below it. There is no correlation between SG and BR classes.

Note: In addition to the classes stipulated in the standard, the range also includes a composition offering resistance to Kalashnikov AK47s.



test of bullet-proof -
Class EN 1063



BR1 BR2 BR3 BR4 BR5 BR6 BR7 SG Kalash

Classification of resistance against firearm attacks - Class EN 1063

					Test conditions			
Class	Type of weapon	Calibre	Type of ammunition	Mass of ammunition (g)	Range (m)	Bullet velocity (m/s)	Number of strikes	Striking distance (mm)
BR1	Rifle	0,22 Long rifle	L/RN	2,6 ± 0,1	10,00 ± 0,5	360 ± 10	3	120 ± 10
BR2	Handgun	9 mm Lugar	FJ¹/RN/SC	8,0 ± 0,1	5,00 ± 0,5	400 ± 10	3	120 ± 10
BR3	Handgun	0,357 Magnum	FJ¹/CB/SC	10,2 ± 0,1	5,00 ± 0,5	430 ± 10	3	120 ± 10
BR4	Handgun	0,44 Rem. Magnum	FJ²/FN/SC	15,6 ± 0,1	5,00 ± 0,5	440 ± 10	3	120 ± 10
BR5	Rifle	5,56 x 45 *	FJ²/PB/SCP1	4,0 ± 0,1	10,00 ± 0,5	950 ± 10	3	120 ± 10
BR6	Rifle	7,62 x 51	FJ¹/PB/SC	9,5 ± 0,1	10,00 ± 0,5	830 ± 10	3	120 ± 10
BR7	Rifle	7,62 x 51 **	FJ²/PB/HC1	9,8 ± 0,1	10,00 ± 0,5	820 ± 10	3	120 ± 10
SG1	Shotgun	Cal 12/70	Solid lead³	31,0 ± 0,5	10,00 ± 0,5	420 ± 20	1	-
SG2		Cal 12/70	Solid lead³	31,0 ± 0,5	10,00 ± 0,5	420 ± 20	3	120 ± 10
* twist length 178 mm approx. 10 mm ** twist length 254 mm approx. 10 mm 1 Plated steel jacket 2 Brass alloy jacket 3 Brenneke slug L Lead CB Coned bullet			FJ FN HC1 PB RN SC SCP1	Full metal jacket Flat nose bullet Steel hard core, mass 3.7 g approx. 0.1 g, hardness > 63 HRC Pointed bullet Round nose bullet Soft core (with lead) Soft core (with lead) and steel penetrator (type SS109)				

AGC range

AGC offers a range of Stratobel glasses which meet the criteria for the different classes within standard EN 1063. For the highest classes, to reduce the thickness of laminated glasses, AGC has also developed a range of double-glazing solutions combining two panes of laminated Stratobel to achieve the desired level of performance.

Range Stratobel

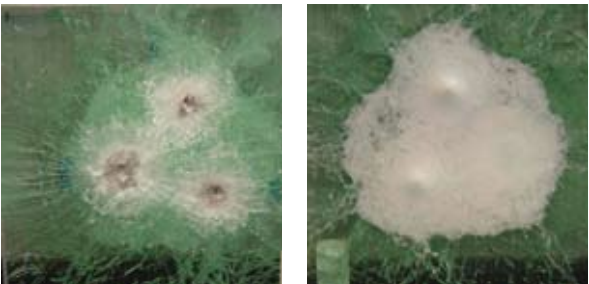
Class	Product	Thickness (mm)	Weight (kg/m ²)
BR1 - S	Stratobel 402-1	14	32
BR1 - NS	Stratobel 802-5	18	42
BR2 - S	Stratobel 003-1	20	47
BR2 - NS	Stratobel 104-1	31	73
BR3 - S	Stratobel 603-1	26	63
BR3 - NS	Stratobel 704-3	37	89
BR4 - S	Stratobel 304-6	33	80
BR4 - NS	Stratobel 1207-1	61	125
BR5 - S	Stratobel 504-4	35	81
BR5 - NS	Stratobel 806-2	58	141
	Stratobel 4207-1	64	127
BR6 - S	Stratobel 1207-1	61	125
BR6 - NS	Stratobel 408-1	74	179
	Stratobel 3209-1	83	176
BR7 - S	Stratobel 6208-1	76	157
BR7 - NS	Stratobel 009-1	80	188
	Stratobel 8209-1	88	188
SG1 - S	Stratobel 304-6	33	76
SG1 - NS	Stratobel 9207-1	69	145
SG2 - S	Stratobel 504-4	35	81
SG2 - NS	Stratobel 9208-1	79	162
Kalashnikov	Stratobel 504-4	35	81

NB:

For safety reasons, the configurations are coded.

*The four-digit codes refer to monolithic laminated glass;
the five-digit codes refer to laminated glass used in an insulating glazing assembly.*

A Stratobel PC range of laminated glasses incorporating polycarbonate components is also available; there is never any splintering on the protected side (NS) of these glasses and they are thinner and lighter but provide the same level of performance.



The pictures opposite show a test sheet of Stratobel PC following a test. Note the three impact points of the bullet on the front of the glass and the corresponding indentations to the polycarbonate on the back.

Range Stratobel PC (Polycarbonate)

Class	Product	Thickness (mm)	Weight (kg/m²)
BR1 - NS	Stratobel PC 810.061	11	20
BR2 - NS	Stratobel PC 815.051	15	31
BR3 - NS	Stratobel PC 819.070	19	41
BR4 - NS	Stratobel PC 823.860	24	51
BR5 - NS	Stratobel PC 835.800	36	81
BR6 - NS	Stratobel PC 841.370	42	93
	Stratobel PC 848i560	49	82
BR7 - NS	Stratobel PC 889.600	90	210
	Stratobel PC 890i100	90	185
SG1 - NS	Stratobel PC 823.860	24	52
SG2 - NS	Stratobel PC 835.800	36	81

NB:
For safety reasons, the configurations are coded.
Codes with an 'i' indicate laminated glass in an insulating-glazing assembly.

8. NATIONAL REGULATIONS AND SAFETY-GLASS APPLICATIONS

8.1. Safety-glass applications

The European standards detailed above set out the classification system for safety glass; they do not specify how a given type of glass should be used depending on its application or location. This is the responsibility of national authorities and standards concerning applications should be published to provide such information.


Where no national regulations exist, the table on pages 16 and 17 give some general information regarding the choice of the appropriate laminated glass depending on its application and the risks it is designed to prevent.

8.2. National regulations

Some countries have published nationally applicable documents and/or standards pertaining to the use of safety glass, at least in terms of accident prevention and protection against falling. For example:

- NBN S 23-002 (STS 38): 2007 in Belgium
- NEN 3569 in The Netherlands
- UNI 7697 In Italy
- others



	Purpose	Corresponding classification		Recommended solutions	Sample applications
Protection of individuals EN 12600	Accident prevention To prevent the risk of cuts and serious injury due to accidental impact against a glass surface or to sharp splinters. Due to their breakage patterns, both toughened glass and laminated Stratobel glass protect against sharp pieces of glass.	1C1 – 1C2 - ... 2B2 – 1B1		Toughened glass  2 panes of glass and 1 PVB min.	Ideal for glass in doors, windows (where there is no risk of falling), shower screens, bus shelters, roof glazing and so forth.
	Protection against falling (defenestration) Where glass surfaces face directly onto an empty space, to prevent individuals falling through the glass, even if it breaks by accident.	1B1		2 panes of glass and 2 PVB min. 	Balcony railings, banisters, spandrels, balustrades, internal partitions, lift partitions, façade glazing to ground level and so forth.
Protection of property EN 356	Protection against vandalism and burglary Basic-level protection: protection against acts of vandalism, throwing of stones, and so forth. Mid-level protection: protection against petty crime. Enhanced protection: protection against premeditated attacks by perpetrators with limited time, the aim being to dissuade them from breaking in and stealing items; even if cracked, the glass remains in place and continues to act as a barrier until it is replaced.	P1A – P2A P3A – P4A P5A		2 panes of glass and 2 PVB min.  2 panes of glass and 4 PVB min.  2 panes of glass and 6 PVB min. 	For private ground-floor residences, commercial office blocks, shop windows, glazing in public buildings and so on and on urban sites, close to stadiums and event locations. May also be used for floors and roofs in villas and apartments. For isolated private residences and for ground-floor commercial office blocks in general. For isolated dwellings in at-risk areas and second homes, at-risk commercial buildings such as pharmacies and specialist shops selling hi-fi and video systems, computers, electrical appliances and/or tobacco/cigarettes, as well as fashion boutiques and shops selling fine leather goods, sports items, perfume and so forth.
	Protection against organised theft In the event of repeated and premeditated manual attack by perpetrators with a larger array of weapons, Stratobel can delay and prevent a break-in and the theft of goods; even if cracked, the glass remains in place and continues to act as a barrier until it is replaced.	P6B – P8B		Multilaminated or Stratobel PC 	Recommended for high-risk shop windows such as jewellers, businesses selling art and antiquities, embassies, prisons, museum display cases and so on.
Protection against firearms EN 1063	Bullet resistance Stratobel provides effective protection against different types of firearm. The appropriate structure should be selected on a case-by-case basis depending on the risks encountered.	BR1 to BR7 SG1 to SG2		Multilaminated or Stratobel PC 	Recommended for counters and glazing in banks, financial establishments, post offices and foreign exchange booths, embassies, vehicles transporting money and so on.
Protection against explosions EN 13541	Explosion resistance Stratobel provides effective protection against explosions. The appropriate structure should be selected on a case-by-case basis depending on the risks encountered.	Consult AGC		Tailor-made configuration	Recommended to protect buildings in the event of an external explosion, for example in the pharmaceutical, chemical and petrochemical industries, banks, embassies and so on.

9. AVAILABILITY

The availability as well as the possible thickness and size of toughened and laminated glasses will vary by market. For further details, please visit www.yourglass.com or contact us.

10. INSTALLATION INSTRUCTIONS

Without going into great detail, three key points should be borne in mind when installing Stratobel laminated glass:

- no water should be left trapped in the rebates;
- setting blocks should be inserted correctly;
- waterproofing materials used should be compatible with the PVB (and any coatings included in the laminated assembly). It is the responsibility of the individuals installing the waterproofing products to check that they are compatible.

Non-symmetrical laminated glasses (resistance against burglary or firearms) and/or double-glazing units including one or more laminated glasses must be installed facing in the correct direction to ensure the desired performance.

Strict rules must also be observed when fitting glass in floors and stairs.

For further details, please consult our «Installation instructions» brochures, which are available upon request or by visiting www.yourglass.com.

NB: In all cases, the thicknesses corresponding to a particular class are merely the minimum applicable according to the test carried out; the actual thicknesses to be used should be determined on a case-by-case basis depending on the size of the glass, the stresses upon it and the installation method to be used.

11. MAINTENANCE, STORAGE, HANDLING AND PROCESSING

Detailed brochures are available on precautions to be taken when storing, handling and processing Stratobel laminated glass and, more specifically, where the composition includes a coated glass.

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