ANNEX A-2

United Nations | Department of Safety and Security

Division of Partnerships and Specialized Support
Physical Security Unit

PHYSICAL SECURITY UNIT INFORMATION BULLETIN Nº 11

SRF AND CABLE CATCHERS

Revised on 10 January 2021

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CONTENT

DISCLAIMER

The Physical Security Unit Information Bulletin (PSU-IB) provides technical advice or standards on topics related to physical protection and equipment.

This Bulletin is not a policy or guideline; it was developed by PSU experts for reference, research, and study purposes, providing best practices, lessons learned and recommendations on the stated topics.

The contents can be changed or updated any time, based on new research or improvements developed by PSU.

Suggestion to improve this Bulletin or ideas for new bulletins can be addressed to psu@un.org.

1. SHATTER RESISTANT FILM (SRF)

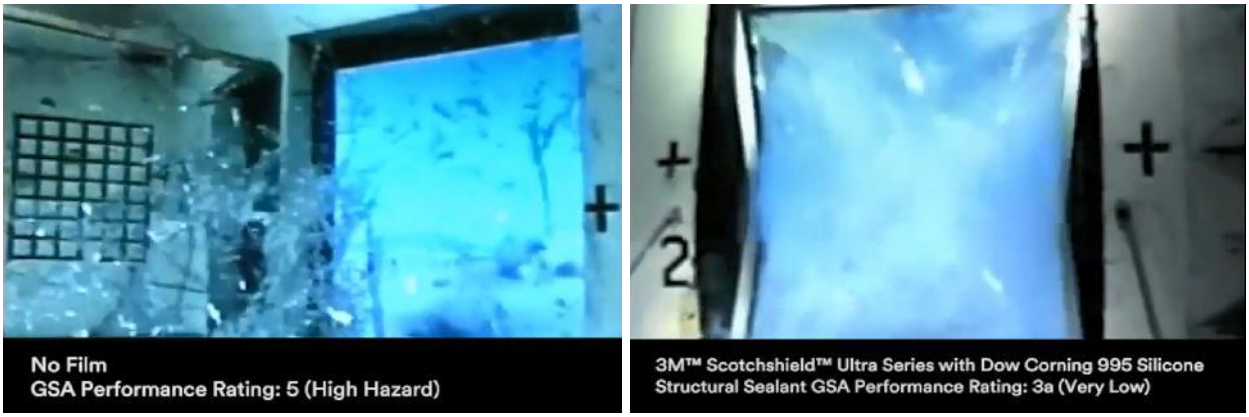
Shatter Resistant Film (SRF) is a polyester laminate film that is applied on the inside face of a pane of glass to mitigate the effects of shattering glass inside a building as a result of an external blast or impact[1].

When properly installed, SRF forms an almost invisible protective coating (membrane) on the interior side of the glass surface. The film is attached to the glass with extremely aggressive pressure sensitive adhesive. This adhesive is applied to the film at time of manufacture and is protected by a release liner until installed. When stress causes the glass to break, the film can stretch and withstand some or all of the energy generated by the stress. The result is that the broken glass may remain within the framing system preventing shards of glass becoming lethal projectiles.

Other names for SRF:

- Anti-Shatter Film (ASF)
- Anti-Fragmentation Film (AFF)
- Fragment Retention Film (FRF)
- Blast Protective Film (BPF)

Windows glazing response without and with SRF:



Source: <https://www.youtube.com/watch?v=jgJMT7viZss>.

SRF can be also used in windows to mitigate deliberate threats, such as:

- Accidental impacts.
- Breaks from burglary or illegal intrusion.
- Windstorms.
- Spontaneous glass breakage due environmental conditions.
- Solar and heating control.

[1] 3M Center. Windows Films for Safety and Security Applications Course. Minneapolis: 3M Corporate Headquarters, 2016.

The security films are tested and certified by international standards, such the previous mentioned standards for blast response. Additionally, they are also tested in specific standard to evaluate the physical properties, such as:

- **ASTM D882** (Standard Test Method for Tensile Properties of Thin Plastic Sheeting), used to test tensile and break strength and other physical properties.
- **ASTM E903-12** (Standard Test Method For Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres), used to test solar performance properties.
- **ANSI Z97.1-2015** (Safety Glazing Materials Used in Buildings - Safety Performance Specifications and Methods of Test), used to test impact resistance.

2. SRF CHARACTERISTICS

There are two types of SRF manufacturing methods:

- **Conventional construction**: single- or double-layer polyester film, with a thick pressure sensitive adhesive on one side of the film and a scratch-resistant hard coat on the other. The performance will be better as the thickness increases. The usual thickness varies from 7 to 14 mils.
- **Micro-layered construction**: uses tens of layers of material in the same thickness as one layer of a conventional film. Micro-layered films alternate between a stiff layer and a gummy layer, to obtain added performance. These alternating layers add strength to the window and add tear resistance to the film.

SRF are also classified and identified based on the follow properties:

- **Physical properties of SRF**: film colour; tensile strength; break strength; tear resistance; thickness; puncture propagation tear.
- **Solar performance properties**: visible light transmission; visible reflection; ultraviolet transmission; solar heat gain coefficient.
- **Performance testing**: impact resistance for safety glazing; windstorm protection; blast protection.

***TIP**: the measurement unit used for SRF thickness is the mil. Mil is one-thousandth of an inch (0.0254 mm); and equals 25.4 microns (micrometres). The thicker the film, less flexible is it. The usual film thickness varies from 4 mils (0.1 mm) to 15 mils (0.38 mm). There is no minimum thickness required by the UN. Although 8 mils (0.2 mm) are the most film used in UN buildings, modern films can absorb similar blast impacts with less thickness.*

All these properties can be used in a technical specification for selection and purchasing. However, the most important property that needs to be analysed is the performance testing. The next figure shows as an example of a technical data sheet from an SRF manufacturer, it is possible to see many physical properties and solar performance properties. However**, the "Film thickness 8 mils" or "Tensile strength 32,000 PSI", does not offer information about the effectiveness of the film under a blast load.**

When analysing the performance testing, it is possible to ascertain if the film will meet the required blast protection by verifying the standard used (GSA and ASTM F1642); the type of glass tested (annealed 6 mm, tempered 6 mm, etc.); the installation method; the blast load (expressed in overpressure and impulse); and finally, the windows response in these conditions.

In this example, the information about the blast load tested (e.g. 9 psi, 60 psi-ms) can be converted as scaled distance Z=16.2. With the scaled distance, blast experts can calculate and create many scenarios of standoff and explosive charge to analyse if the window protection is sufficient.

Example of SRF technical information:

Performance Testing*

Method	Glass Substrate	Film Attachment	Rating	
Safety Glazing				
16 CFR 1201	¼" & 1/8" annealed	--	Category 2, 400 ft-lbs	
ANSI Z97.1			Class A (Unlimited), 400 ft-lbs	
Impact Resistance				
ASTMs E1886 / E1996	¼" tempered	IPA	Large Missile C, +/- 75 psf	
ASTM E330	3/16" tempered		+/- 100 psf	
Blast Mitigation			**Blast Load**	**Rating**
GSA TS01-2003 / ASTM F1642	¼" annealed	IPA	9 psi, 60 psi*msec	GSA Level 2 / ASTM "Minimal Hazard"
		IPP	7 psi, 42 psi*msec	GSA Level 2 / ASTM "Minimal Hazard"
	¼" tempered	IPA	9 psi, 60 psi*msec	GSA Level 2 / ASTM "No Hazard"
		IPP	7 psi, 42 psi*msec	GSA Level 2 / ASTM "Minimal Hazard"
	1" double pane (annealed)	IPA	10 psi, 80 psi*msec	GSA Level 2 / ASTM "No Hazard"
		IPP	9 psi, 60 psi*msec	GSA Level 2 / ASTM "Minimal Hazard"

*Glazing systems vary. Contact 3M for more information.

Film Properties (nominal)

Film Thickness	8 mils
Film Construction	Micro-layered
Tensile Properties (ASTM D882)	
Tensile Strength	32,000 psi
Break Strength	255 lbs/in
Elongation at Break	130%
Yield Strength	15,000 psi
Elongation at Yield	9%
Modulus	473 kpsi

Graves Area Tear Resistance (ASTM D1004)	1,200 lbs%
Puncture-Propagation-Tear Resistance (ASTM D2582)	9.5 lbf
Puncture Strength (ASTM D4830)	185 lbf
Abrasion Resistance (ASTM D1044)	3% Δ haze
Peel Strength (ASTM D3330)	6 lb/in
Flammability (ASTM E84)	Class A
Solar Properties – *film applied to ¼" clear glass*	
Visible Light Transmitted	87%
UV Light Rejected	99.9%

Source: http://www.3m.com

3. SRF INSTALLATION METHODS

The SRF is applied on the inside face of a pane of glass. There is two ways to install the SRF on the windows glazing:

- Daylight application.
- Attached application, that is subdivide in wet/dry-glazed or mechanical installed.

Daylight installation:

- The most common and cheaper application.
- The film does not extend into the rebates of the window pane surround.
- The film is applied to the inside face of the glass with a 1 to 3mm gap between the edge of the film and the frame.
- This allows the liquid used in the application of the film to the glass surface to be pushed to the edge and wiped away, leaving a daylight area around the perimeter of the film.
- The application of SRF must, at a minimum, cover the clear area (the portion of the glass unobstructed by the frame) of the window.
- This minimum application to the exposed glass without any means of attachment or capture within the frame, termed “daylight” installation, is commonly used for retrofitting windows. However, **the effectiveness is almost insignificant for blast protection**.

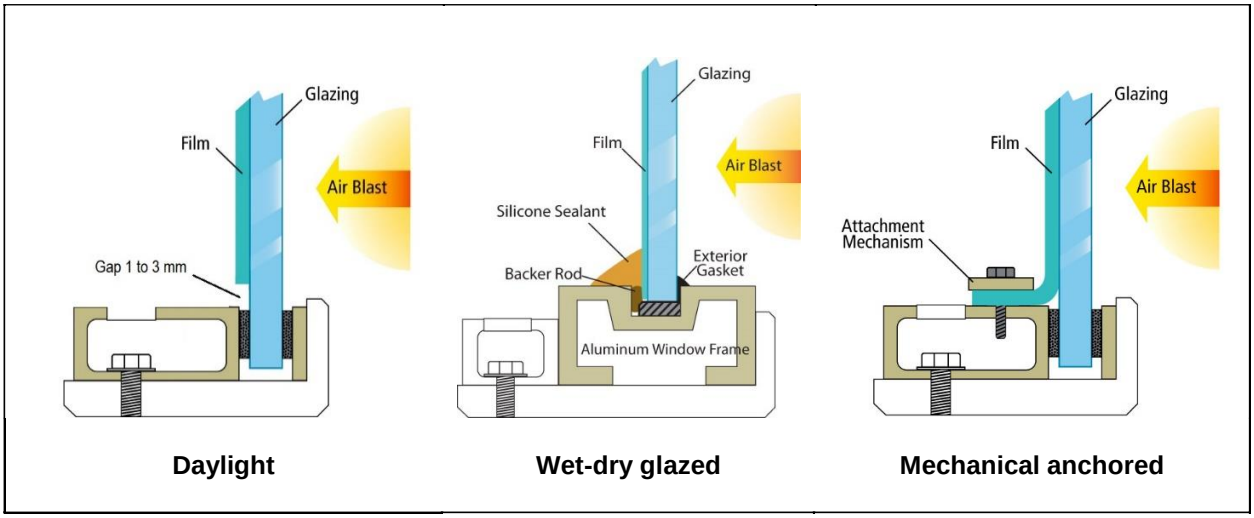
Attached, wet/dry glazed installation:

- The SRF is positively attached to the frame using a high strength liquid sealant such as silicone.
- Frequently used for field retrofits, the method allows the flexible frame to deform slightly, reducing glass fragments entering the building and offering more protection than the daylight installation.
- It is costlier than the daylight installation system; however, is less expensive than the mechanically attached.
- Dry-glaze attachment is used with a daylight application of SRF, the system employs an extruded rubber batten which creates a factory-made triangular joint around all four perimeter sides of a window, attaching the filmed glass to the frame.

Attached, mechanically anchored:

- The SRF is positively attached to the frame employing screws and/or batten strips to attach the film to the frame.
- While a film may be effective in keeping glass fragments together, it may not be particularly effective in retaining the glass in the frame. Securing the film to the frame with a mechanically connected anchorage system further reduce the likelihood of the glazing system exiting the frame.
- Because additional framework is necessary, the mechanical attachment method can be less aesthetically pleasing than the wet glazed installation system.
- The installation can be limited depending on the type of frame.

SRF installation methods:



Source: <http://www.johnsonwindowfilms.com/protective-films/anchoring-systems/>.

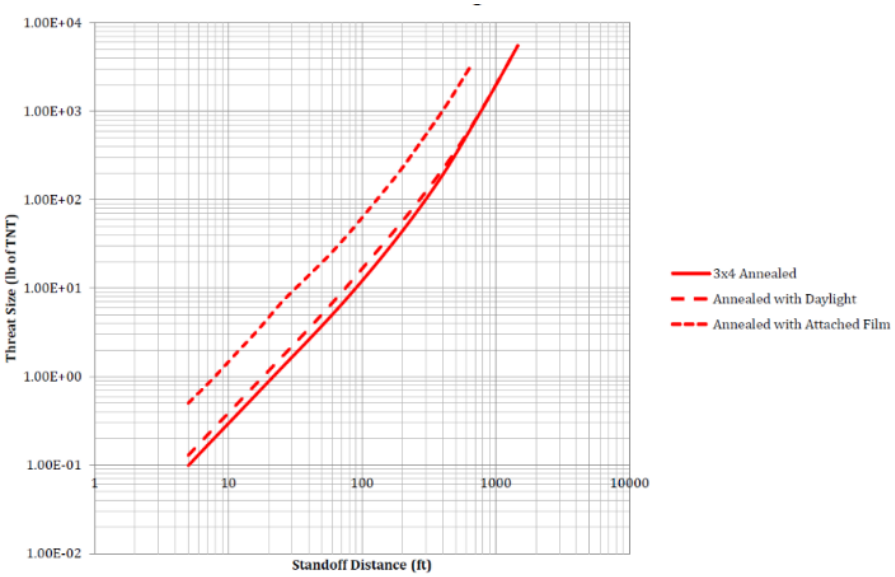
TIP: *Daylight application is the most common and cheaper method for SRF. It is very popular in UN premises and a good option to avoid accidental impacts and burglary attempts. However, it is not appropriate for blast protection. If a blast threat exists, the Attached application provides more protection.*

The effectiveness of the SRF depends on the installation method. The attached methods are definitively more effective for blast protection than the daylight method. The next chart presents results of tests presented by Stone Security Engineering; an American Company specialized in blast protection. The main manufactures of safety films, such as 3M® and Madico®, also recommend attached installation instead of the daylight method.

Installation of SRF in attached methods:

Source: PSU files.

SRF effectiveness based on installation methods:



Source: Stone Security Engineering.

Given that there are many variables to be considered when evaluating the effectiveness of SRF, including the blast variables, window type, and type of protection in place, assessments of these types should be conducted using blast evaluation tools discussed. As a basic reference, however, the following Table can be used to provide a rough estimate of SRF protectiveness.

Examples of SRF effectiveness:

Product	Glass	Film	Blast Load	Z	Examples of conditions		GSA Rating	ASTM Rating
					Charge	Distance		
3M Scotchshield Ultra S800®	Annealed 6 mm	Attached IPA (*)	9 psi 60 psi-ms	6.4	100 kg	30 m	**2**	**3 Minimal**
					50 kg	24 m		
					10 kg	14 m		
	Tempered 6 mm	Attached IPA (*)	9 psi 60 psi-ms	6.4	100 kg	30 m	**2**	**2 No hazard**
					50 kg	24 m		
					10 kg	14 m		
	Annealed 25 mm 2 panes	Attached IPA (*)	10 psi 80 psi-ms	6.0	291 kg	40 m	**2**	**2 No hazard**
					50 kg	23 m		
					10 kg	13 m		
Madico SafetyShield 800®	Annealed 6 mm	Daylight	12.78 psi 78.79 psi-ms	5.3	187 kg	30 m	**3b**	**5 Low Hazard**
	Annealed 6 mm	4 side structural silicon bead	12.78 psi 78.79 psi-ms	5.3	187 kg	30 m	**3a**	**5 Low Hazard**
	Annealed 6 mm	Attached FrameGard (**)	9.9 psi 64.53 psi-ms	6.1	155 kg	33 m	**2**	**3 Minimal**
					50 kg	22 m		
					10 kg	13 m		
(*) 3M Impact Protection Adhesive Attachment System® (**) Madico FrameGard Anchoring System								

4. SPECIFICATIONS, WARRANT, AND REPLACEMENT

The technical specification should be prepared based on the performance conditions of the SRF, not only the film properties. If specified only based on film properties, the manufacturer or vendor will provide just what were requested, but no warrant about the effectives of the film.

Additional requirements to be included in the specifications of the film:

- To be required an Authorized Dealer/Applicator (ADA). The ADA shall provide documentation that the ADA is authorized by the manufacturer of the film to install said window film as per the manufacturer's specifications and in accordance with specific requests as to be determined and agreed to by the costumer.
- Authorization of dealership should be verified through the manufacturer.
- The ADA should provide commercial buildings reference list of 10 properties or more where the ADA has installed window film.
- To be required to the manufacturer ensure proper quality control during production, shipping and inventory, clearly identity and label each film core with the product designation and run number.
- Proper certification of performance conditions of the film response based on acceptable international standards.
- Warrant for a minimum 10 years (some manufactures offer 12 years) from installation, and provided that the product is maintained in accordance with the window film properties.

The warrant must cover:

- Maintain Solar Reflective Properties without cracking, crazing, or peeling.
- Maintain Adhesion Properties without blistering, bubbling, or delaminating from the glass.
- Maintain Appearance without discoloration.
- Maintain Strength, Tear, and Penetration Resistant Properties as defined in product literature.

During the warrant time, the occurrence of these mentioned failures or lost of properties can be caused by bad quality of the film or bad quality of installation. In this case, if the product does not conform to the warranty, the sole and exclusive solution, to be mentioned in the technical specification is:

- Replacement of the Quantity of Film proved to be defective; and
- Provide Removal and Reapplication Labour of like quality Product free of charge.

5. CABLE CATCHER SYSTEMS

Window catcher systems are devices spanning across a window, positively attached to the window frame, or building structure, that stop the glass panel from entering an occupied space in case of an external blast. The next figure illustrates a test where a window was retrofitted with SRF, but the frame and anchoring were not strong enough to absorb the blast load and the entire panel is projected.

Windows with SRF but not properly anchored:

Source: <https://www.youtube.com/watch?v=qlfWtGWG6To>.

The catching system will not prevent the blast effects, but only mitigate the damage caused by the window panel being propelled inside a room. Also, the windows must use laminated glass or glass retrofitted with Shatter Resistant Film (SRF). If there is no SRF on the windows, or the SRF is weak, the glass will be cracked, and the fragments will fly through the room.

***TIP**: take attention on the type of windows opening before install windows catchers. The opening can become limited. It is necessary to consider if the windows is a escape route for fire or other emergency. Windows catchers will close the route.*

There are three types of catching systems:

- Rigid Catch Systems.
- Cable Catch Systems.
- Bomb Blast Net Curtains (BBNC).

Rigid Catcher Systems consists of steel bars crossing the windows. The rigid catch bars intercept the filmed or laminated glass and disrupt its flight; however, they tend to break the dislodged glazing into smaller projectiles. Catch bars are only effective if they are distributed along the mass of the glass panel. Rigid catch systems are subject to huge forces upon impact and require considerable anchorage into a very substantial structure to prevent failure. Where either the attachments or the supporting structure is incapable of restraining the forces, the catch system will be dislodged and become part of the debris.

Examples of rigid catcher system, anchored horizontally:

Source: PSU files.

Cable Catcher Systems consist of steel wire cables crossing the windows. Also called as energy-absorb catch system. They are used extensively to absorb significant amounts of energy upon impact, and their flexibility makes them easily adaptable to many situations. Cable systems have long been recognized as an effective means of stopping massive objects moving at high velocity. The diameter of the cable, the spacing of the strands, and the means of attachment are all critical in designing an effective catch system. An analytical simulation or a physical test is required to confirm the adequacy of the cable catch system to restrain the debris resulting from an explosive event. High-performance energy-absorbing cable catch systems retain glass and frame fragments and limit the force transmitted to the supporting structure. Typical cable catchers consist of a series of 6 mm (0.25 inch) diameter stainless steel cables connected with a shock-absorbing device to an aluminium box section, which is attached to the jambs, the underside of the header, and topside of the sill.

Examples of energy-absorbing cable catcher system, anchored vertically or horizontally:

Source: PSU files.

Bomb Blast Net Curtains (BBNC) consist in a flexible ballistic curtain that cover the entire window. Blast curtains are affixed to the interior frame of a window opening and essentially catch the glass fragments produced by a blast wave. The debris is then deposited on the floor at the base of the window. The use of these curtains does not eliminate the possibility of glass fragments penetrating the interior of the occupied space, but instead limits the travel distance of the airborne debris. The hazard level to occupants is significantly reduced, but a person sitting directly adjacent to a window outfitted with a blast curtain may still be injured by shards of glass. The curtain will billow out about 1 meter during a blast event. The curtains may either be anchored at the top and bottom of the window frame or anchored at the top only and outfitted with a weighted hem. The curtains should be extra-long, exceeding the height of the window, with the surplus either wound around a dynamic tension retainer or stored in reservoir housing.

Examples of blast curtains:

Source: PSU files.

***TIP**: Rigid and cable catch systems should be used in windows retrofitted with SRF. However, blast curtains should be used in windows without SRF. If SRF is used in blast curtains, the projection of the entire panel will likely rip the curtain.*

6. INSTALLATION OF CABLE CATCHERS

Although window catchers are a popular blast mitigation measure in UN, **this method is considered an improvised mitigation**, because there are no national or international standard regulating the use of window catchers, nor scientific studies proving their effectiveness.

Even the UFC 4-010-01 Minimum Antiterrorism Standards for Buildings (US DoD, 2018), states that windows retrofits incorporating alternative window treatments such as fragment retention films and blast curtains are not acceptable alternatives for new buildings or existing buildings.

The installation of these systems is based on best practices and there is no guarantee that it will increase safety and stop the windows panel projection. This is exactly the opposite of SRF, that is regulated by international standards and testing methodologies, as well as certifications of specialized testing laboratories ensuring the quality of the product.

Windows catchers are subject to huge forces upon impact and require considerable anchoring into a very substantial structure to prevent failure. Where neither the attachments nor the supporting structure can restrain the forces, the catch system will be dislodged and become part of the debris.

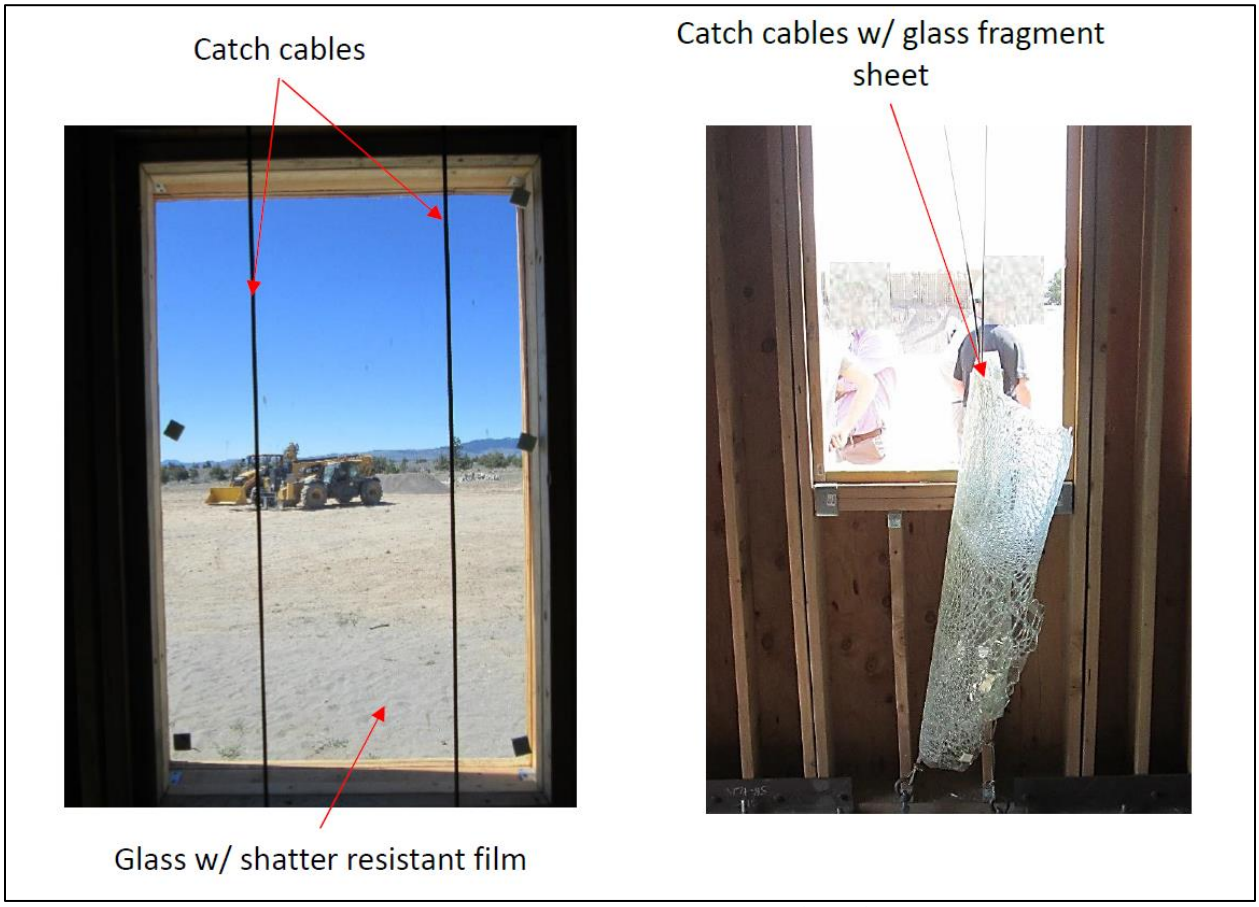
The main concern should be the anchoring. The windows catchers can be anchored vertically or horizontally, depending on the column or beam structure. The structure must be strong enough to absorb the impact of the entire windows flying with the blasting, as well the anchorage system used. Typically, columns, slabs and beams are the stronger structural elements in buildings, reason which is better to anchor the cables vertically, fixing them in the slab and roof beam.

The quantity of bars or cables per windows is variable, depending of the size and proportion (height and length) of the windows. As explained before, there is no standard regulating the quantity of cables or bars in a window. Best practices recommend one bar or cable each 0.5 m (fifty centimetres), horizontally or vertically from the centre of the windows.

In a research developed and tested by Stone Security Engineering and Oregon Blast Laboratory (OBL) in 2018 and submitted to the American Society of Civil Engineers (ASCE)[2], Sission and Montalva recommend a "rule of thumb" for designing Cable Catcher Systems to resist both window glass and frame is to use a **minimum of two cables** per window frame to better protect against window frame projectiles.

[2] Sisson, T & Montalva, A. **Mitigation of Glass Hazards in High Threat Environment using Cable Catch Systems**. New York: Stone Security Engineering, 2018.

Test on cable catcher system:



Source: Stone Security Engineering (2018)

Recommendations for rigid bars:

- For a rigid catch system, a solid steel bar with 12 mm diameter (½ inches) with average rupture point of 30 kN or 3,000 kgf is used.
- The bar must be constructed in a unique piece, with the extremities prepared as screw to receive a nut, at least 20 mm diameter or to the bars should be a plate welded in their extremities and fixed with concrete sleeve anchor.
- The recommended plate is 5 mm thickness, 10 x 10 cm size, square or round shape, with 4 screws holes each side.

Recommendations for steel cables:

- For wire steel cables, to use at least 6 mm diameter (¼ inches) with average rupture point of 30 kN or 3,000 kgf.
- There are several characteristics of the steel wire cables, as direction strands lay, the relationship between the direction strands lay in the rope, the length along the rope, etc. As a general rule, a strand made up of a small number of large wires will be more abrasion resistant and less fatigue resistant than a strand of the same size made of many smaller wires.

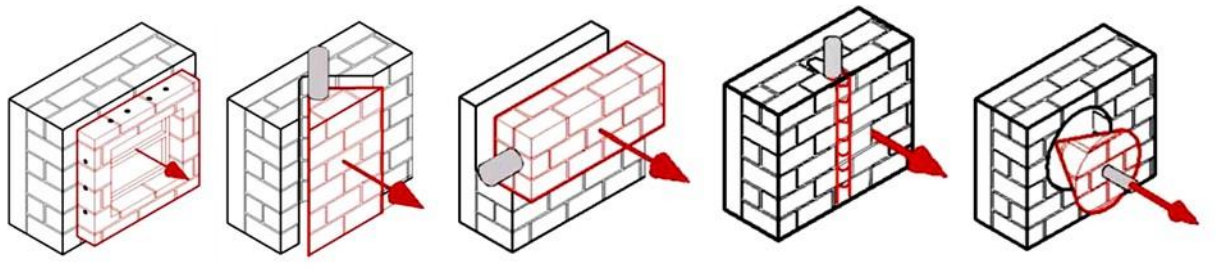
- The cable catcher will work in a fixed point, without constant movement. So, steel cables with large wires are preferable because the fatigue resistance is not more essential than abrasion resistance.

The resistance of bars and cables can change based on the quality or steel. A mechanical engineer can provide detailed advising in the selection and installation of windows catchers.

Anchoring of cable catchers: Anchoring is a critical issue in the windows catchers. The anchoring point can be the columns (horizontally lines) or the beams (vertically lines). In some cases, the wall can be used also as anchoring point since that the wall is strong enough to sustain the impact of windows projection in case of blast.

The next figure illustrates possibilities of failures that can occur in the anchorage of windows catchers, such as perimeter shear failure; masonry shear failure; anchor body shear failure; mortar joint failure; bearing failure; tensile failure.

Failures on cable catcher's anchorage:



Source: WARD & JORDAN (2018)

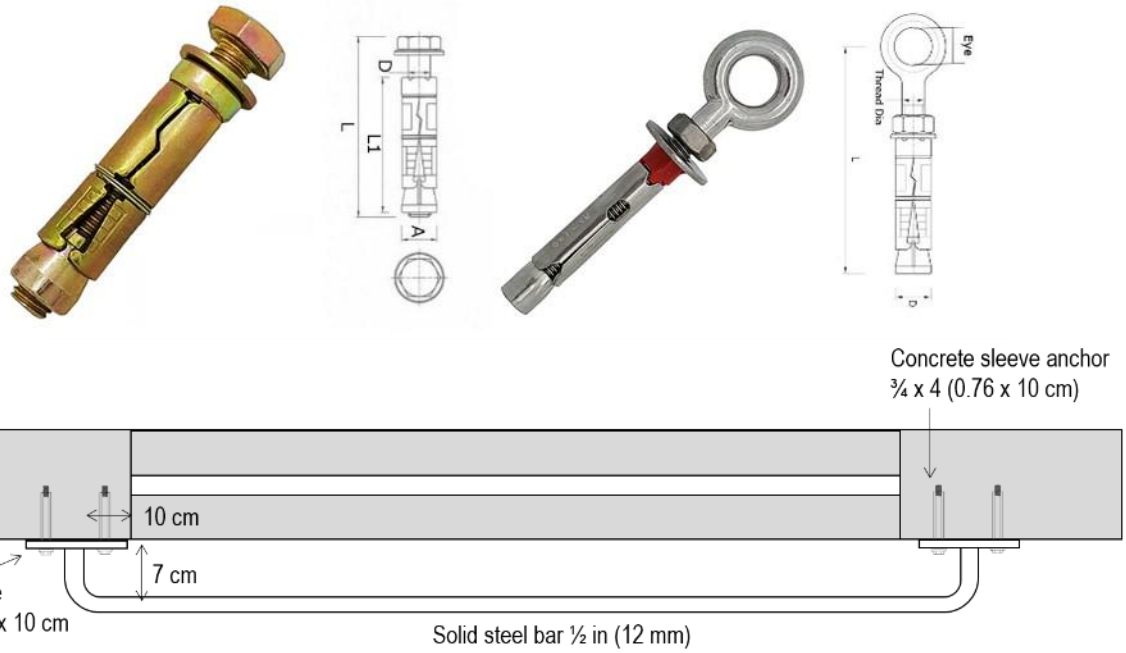
Recommended anchoring for concrete walls:

- The bars should be a plate welded in their extremities and fixed with concrete sleeve anchor, stainless steel, at least 8 mm diameter and 10 cm length.
- The cables should be fixed in steel eye bolt with anchor shield plug expansion, at least 8 mm diameter and 10 cm length.
- This anchoring system can be used in reinforced masonry walls if the contractor guarantees the same strength of the anchorage in concrete walls.

Recommended anchorage for non-concrete walls:

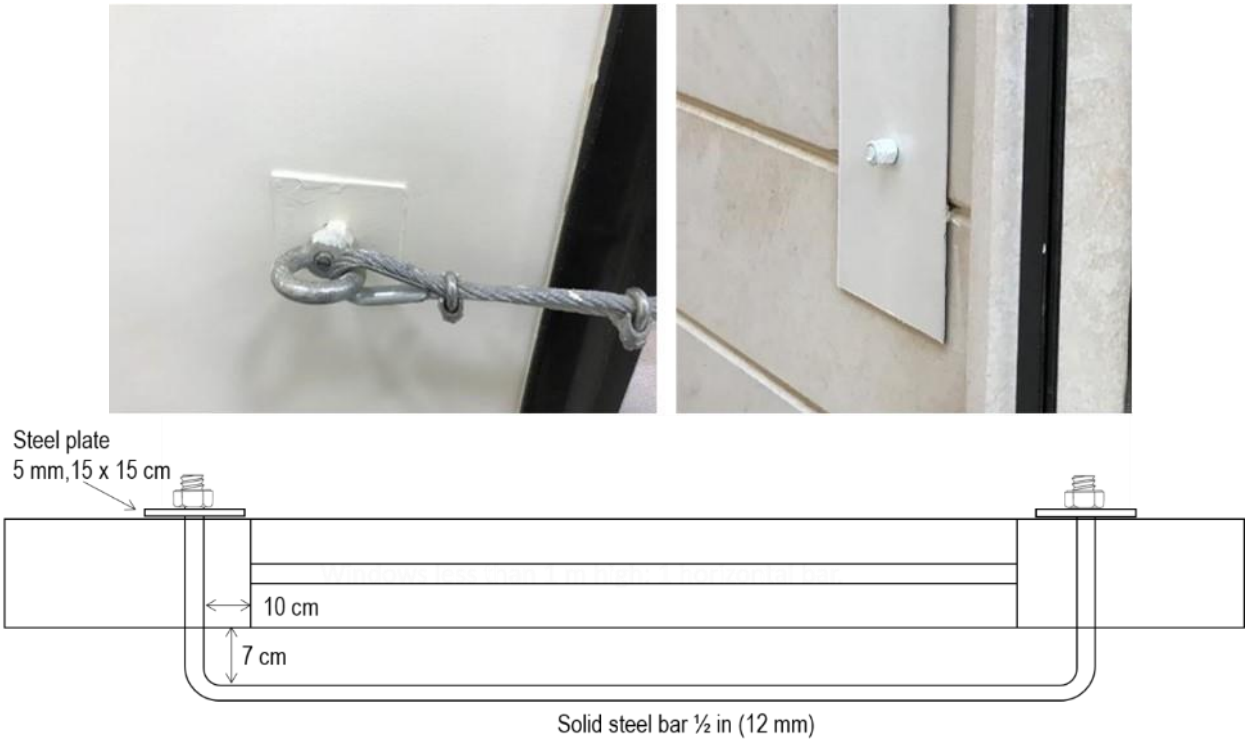
- This system is recommended to be used in masonry or cement block walls, where supposed that the walls is not strong to enough to anchor the bars.
- The bars or the eye bolt anchor should cross the wall and be reinforced with metal plates in the exterior face.
- The screw nut should be fixed on a steel plate 5 mm thickness in dimensions 15 x 15 cm, square or round shape.

Examples of concrete sleeve anchors and anchoring in concrete walls:



Source: PSU files.

Examples of anchorage in non-concrete walls:



Source: PSU files.

***TIP**: Considering that is no standard regulating the use of windows catchers to blast protection of windows, it is recommended to consult a mechanical or civil engineer before installations of these devices.*

***TIP**: Consider retrofitting **the anchoring of the windows frame** instead to use cable catchers. It less expensive and more efficient.*

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