



Consulting Report

on

FEM Simulation of Life Shield Clear Panels

with Cable Catchers under Blast

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Prepared for: Life Shield Engineered Systems, LLC

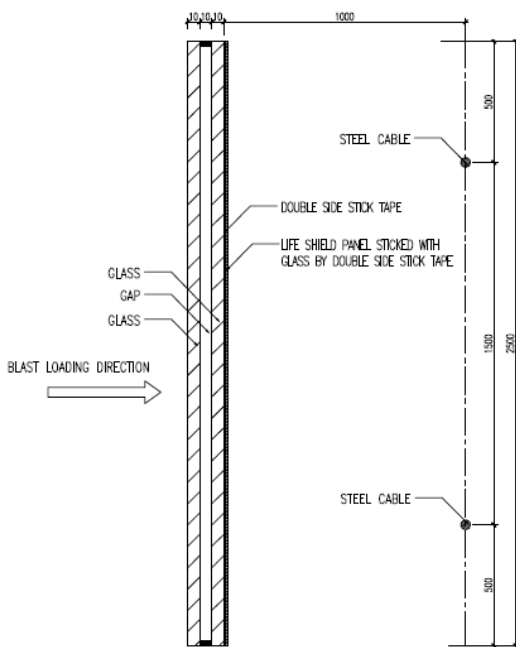
A subsidiary of The Sherwin-Williams Company

and

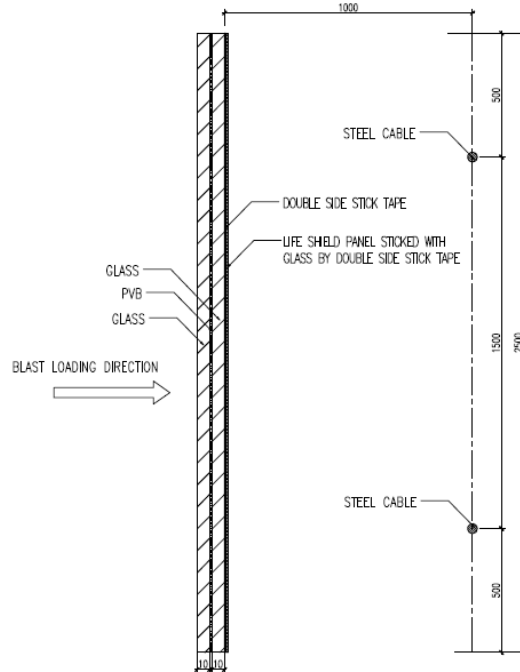
K&C Protective Technologies(Beijing) Co., Ltd

1. Test Description

The structure detailed below was used as the basis of design for the application of various blast loadings to determine the efficacy of protective retrofits using various Life Shield[®] technologies in window applications. Attachment design was engineered by K&C Protective Technologies Pte. Ltd.



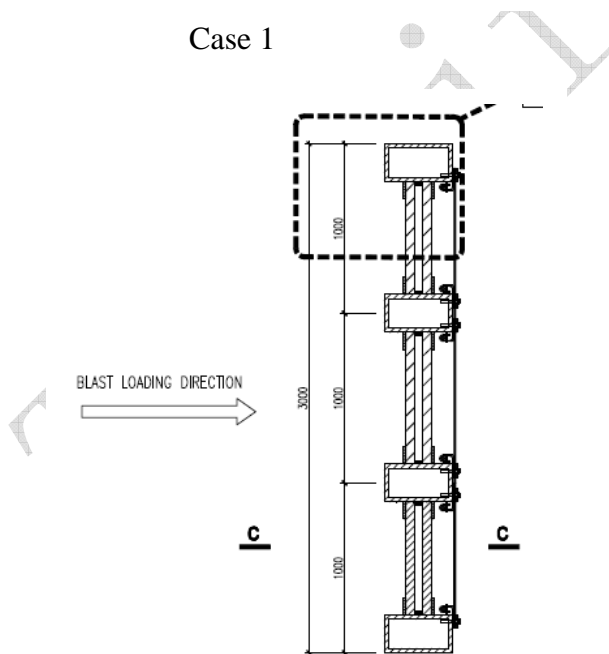
SECTION A-A
SCALE: 1:3



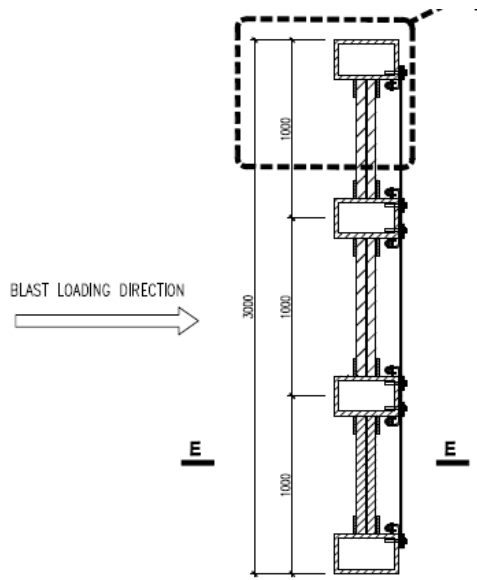
SECTION B-B
SCALE: 1:3

Case 1

Case 2



Case 3



Case 4

2. Modeling Description

- Software: ANSYS & LS-DYNA
- Material: Models & parameters (see Table 1 & Table 2)

Table 1 Summary of the Material Models

Material	Model	Element
Glass	*MAT_ELASTIC *MAT_ADD_EROSION	Solid164
PVB	*MAT_VISCOELASTIC *MAT_ADD_EROSION	Solid164
Life shield panel	*MAT_PLASTIC_KINEMATIC *MAT_ADD_EROSION	Solid164
Aluminum frame	*MAT_ELASTIC	Solid164
Steel cable	*MAT_CABLE_DISCRETE_BEAM	Link167

Table 2 Summary of the Material Parameters

Material	Elastic modulus N/m ²	Poisson's ratio	Density kg/m ³	Yield stress N/m ²	Tangent modulus N/m ²	Breaking stress N/m ²
Glass ⁽¹⁾	7×10^{10}	0.33	2800			
PVB ⁽¹⁾	7×10^{10}	0.22	2560			8×10^7
Life shield panel ⁽²⁾	4.2×10^8	0.49	1250	1.6×10^7	1.1×10^7	4.3×10^7
Aluminum frame ⁽¹⁾	3.3×10^8	0.49	1100			3.0×10^7
Steel cable ⁽¹⁾	2×10^{11}	0.31	7840			

(1) Data from literature.

(2) Data provided by the Sherwin-Williams Company.

- Geometry information (see Table 3)

Table 3 Summary of Geometry Parameters

Case 1	Glass thickness		Life shield panel thickness	Steel cable diameter	Glass size
Dual pane	1.0cm		0.3cm	1.5cm	250cm×50cm
Case2	Glass thickness	PVB thickness	Life shield panel thickness	Steel cable diameter	Glass size
Laminated glass	1.0cm	0.3cm	0.3cm	1.5cm	250cm×50cm
Case 3	Glass thickness		Life shield panel thickness	Beam and column	Steel cable diameter
Dual pane	1.0cm		0.3cm	□6×6×0.5	1.5cm
Case4	Glass thickness	PVB thickness	Life shield panel thickness	Beam and column	Steel cable diameter
Laminated glass	1.0cm	0.3cm	0.3cm	□6×6×0.5	1.5cm

- Supporting condition (see Table 4)

Table 4 Summary of Supporting Condition

Case No.	Supporting	Fixed condition
Case 1, Case 2	Four-Point-supported	Fixed at the supports
Case3, Case 4	Framed	Fixed at the both ends of columns

- Loading Case (see Table 5)

Table 5 Summary of Loading Case

Loading case	Charge	Distance	Overpressure	Duration
Small load	25kg	5m	238.1kPa	5.7ms
Large load	1000kg	20m	172kPa	21.2ms

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3. Results

Simulation results utilizing LS-Dyna Finite Element modeling are shown below. The results were then interpreted in terms of the US General Services Administrations Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loadings and ISO 16933 Glass in building — Explosion-resistant security glazing — Test and classification for arena air-blast loading (See Appendix 1 for summary) performance criteria.

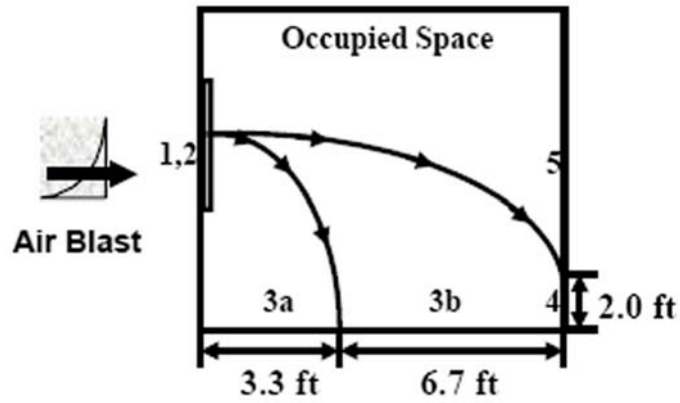
Table 5 Summary of the Cases Analyzed

Case	Glass type	Frame	LCS(V)-100 Attachment	Secondary System	Blast Load	Result	Performance Level	
							GSA	ISO
1	Dual pane	None	VHB Tape	Cables	20kg@5m	Pass	2	B
1a	Dual pane	None	VHB Tape	Cables	1000kg@20m	Fail	5	F
2	laminated	None	VHB Tape	Cables	20kg@5m	Pass	2	B
2a	laminated	None	VHB Tape	Cables	1000kg@20m	Fail	5	F
3	Dual pane	Mullions with cables	Mechanical to mullion cable	None	20kg@5m	Pass	2	B
3a	Dual pane	Mullions with cables	Mechanical to mullion cable	None	1000kg@20m	Pass	2	B
4	laminated	Mullions with cables	Mechanical to mullion cable	None	20kg@5m	Pass	2	B
4a	laminated	Mullions with cables	Mechanical to mullion cable	None	1000kg@20m	Pass	2	B

The detailed LS-DYNA analysis can be found in the Tongji University Report in Appendix B.

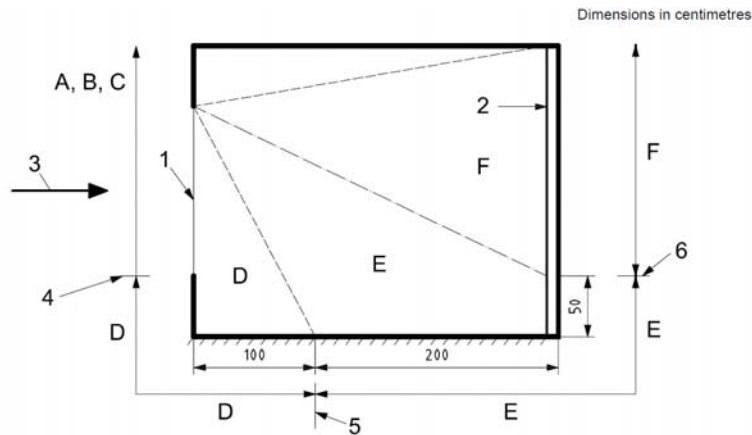
APPENDIX 1

US General Services Administrations Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loadings



Performance Condition	Protection Level	Hazard Level	Description of Glazing Response
1	Safe	None	Glazing does not break. No visible damage to glazing or frame.
2	Very High	None	Glazing cracks but is retained by frame. Dusting or very small fragments near sill or on floor acceptable.
3a	High	Very Low	Glazing cracks. Fragments enter space and land on floor no further than 3.3ft from the window.
3b	High	Low	Glazing cracks. Fragments enter space and land on floor no further than 10ft from the window.
4	Medium	Medium	Glazing cracks. Fragments enter space and land on floor and impact a vertical witness panel at a distance no more than 10ft from the window at a height no greater than 2ft above the floor.
5	Low	High	Glazing cracks and window system fails catastrophically. Fragments enter space impacting a vertical witness panel at a distance of no more than 10 ft from the window at a height greater than 2ft above the floor.

ISO 16933 Glass in building — Explosion-resistant security glazing — Test and classification for arena air-blast loading



- Key**
- 1 window
 - 2 witness panel
 - 3 blast
 - 4 very low hazard threshold
 - 5 low-hazard threshold
 - 6 high-hazard threshold
- A to F hazard ratings:
- A no break
 - B no hazard
 - C minimum hazard
 - D very low hazard
 - E low hazard
 - F high hazard

Hazard rating	Hazard-rating description	Definition
A	No break	The glazing is observed not to fracture and there is no visible damage to the glazing system.
B	No hazard	The glazing is observed to fracture but the inner, rear face leaf is fully retained in the facility test frame or glazing system frame with no breach and no material is lost from the interior surface. Outer leaves from the attack face may be sacrificed and may fall or be projected out.
C	Minimal hazard	The glazing is observed to fracture. Outer leaves from the attack face may be sacrificed and may fall or be projected out. The inner, rear face leaf shall be substantially retained, with the total length of tears plus the total length of pullout from the edge of the frame less than 50 % of the glazing sight perimeter. Also, there are no more than three rateable perforations or indents anywhere in the witness panel and any fragments on the floor between 1 m and 3 m from the interior face of the specimen have a sum total united dimension of 250 mm or less. Glazing dust and slivers are not accounted for in the hazard rating. If by design intent there is more than 50 % pullout but the glazing remains firmly anchored by purpose-designed fittings, a rating of C (minimal hazard) may be awarded, provided that the other fragment limitations are met. The survival condition and anchoring provisions shall be described in the test report.
D	Very low hazard	The glazing is observed to fracture and significant parts are located no further than 1 m behind the original location of the rear face. Parts be projected any distance from the attack face towards the blast source. Also, there are no more than three rateable perforations or indents anywhere in the witness panel, and any fragments on the floor between 1 m and 3 m from the interior face of the specimen have a sum total united dimension of 250 mm or less. Glazing dust and slivers are not accounted for in the rating.
E	Low hazard	The glazing is observed to fracture, and glazing fragments or the whole of the glazing fall between 1 m and 3 m behind the interior face of the specimen and not more than 0,5 m above the floor at the vertical witness panel. Also, there are 10 or fewer rateable perforations in the area of the vertical witness panel higher than 0,5 m above the floor and none of the perforations penetrate more than 12 mm.
F	High hazard	Glazing is observed to fracture and there are more than 10 rateable perforations in the area of the vertical witness panel higher than 0,5 m above the floor, or there are one or more perforations in the same witness panel area with fragment penetration more than 12 mm.