NATIONAL GLASS ASSOCIATION with GANA

Glass Technical Paper **FB12-07 (2018)**

Blast Resistant Glazing

Introduction

Blast resistant glazing is typically used reduce injury from flying glass debris resulting from blast shock waves (over-pressures). When properly designed, framed, and anchored, blast resistant glazing is also capable of maintaining the integrity of the building envelope following an explosion which in turn reduces injury to building occupants and minimizes the surrounding debris field. This document deals with the glazing infill, namely laminated glass and organic-coated glass. Laminated glass is defined as factory fabricated glazing with at least two pieces of glass or plastic glazing bonded together with a high performance polymer interlayer. Like laminated glass, organic-coated glass is also a glass-plastic composite, but the high-performance polymer layer is typically used as a retrofit and is applied to the innermost glass surface. This polymer layer, such as an adhesive-backed films also known as fragment retention films, can be either factory-applied or applied as a retrofit to existing windows. Adding the polymer layer to the innermost glass surface helps reduce glass spall and hazardous debris in a blast event. Blast resistant glazing must conform to applicable criteria and specifications through analysis, testing, or a combination of both methods.

Design Manuals

Blast design criteria is outlined in applicable design manuals and should be clearly described in project specifications. There are four main North American government design manuals that apply depending on the type of facility:

ISC Standards – *The Risk Management Process for Federal Facilities: An Interagency Security Committee Standard Appendix B: Countermeasures (FOUO)* for General Services Administration (GSA) Facilities

OBO Design Standards – U.S. Department of State Bureau of Overseas Buildings Operations (OBO) *Design Standards*

UFC 4-010-01 – Unified Facilities Criteria (UFC) Department of Defense (DoD) *Anti-terrorism Standards for Buildings*

VA PSDM – U.S. Department of Veterans Affairs *Physical Security Design Manual for Life Safety Protected or Mission Critical Facilities*

Standards related to blast resistant glazing analysis and design are:

ASTM E1300 – *Standard Practice for Determining Load Resistance of Glass in Buildings*

ASTM F2248 – *Standard Practice for Specifying an Equivalent 3-Second Duration Design Loading for Blast Resistant Glazing Fabricated with Laminated Glass*

PDC-TR 10-02 – *Blast Resistant Design Methodology for Window Systems Designed Statically and Dynamically*

Blast design can be performed on components (glazing or frames) using simplified analysis methods such as a single-degree-of-freedom (SDOF) analysis or on the entire glazed fenestration system using high-fidelity finite element analysis (FEA). All design tools or analysis methods should be validated using blast or shock tube test data. Commonly used validated SDOF design tools for glazing include SBEDS-W, WinGARD PE, and HazL.

ASTM F2248 is a practice for static design of glazing. It sets forth a method to specify an equivalent 3-second design loading suitable to use with ASTM E1300 to select the thickness and type of blast resistant glazing fabricated with laminated glass to glaze a fenestration. ASTM F2248 applies to laminated glass only, including single laminated glass and insulating glass fabricated with laminated glass. Monolithic glazing, plastic glazing, and security film applied to existing glazing are not covered by this ASTM standard. It also assumes that the laminated glass will attach to the supporting frame that restrict deflection of the glazing edges to L/60 under twice the equivalent 3-second duration design loading and that structural silicone sealant or adhesive glazing tape are used with adequate bite. Therefore this practice cannot be used for dry-glazed glazing.

Test Standards

Blast testing can be conducted on the glazing infill or the entire glazed fenestration system. There are two North American test methods that are most often used for blast testing:

ASTM F1642 – *Standard Test Method for Glazing and Glazing Systems Subject to Airblast Loadings*

GSA-TS01 – US General Services Administration *Standard Test Method for Glazing and Window Systems Subject to Dynamic Overpressure Loadings.*

The other specifications and standards related to testing of blast resistant glazing are:

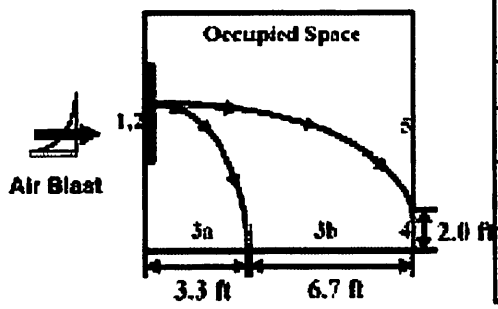
AAMA 510 – *Guide Specification for Blast Hazard Mitigation for Fenestration Systems*

ASTM F2912 – *Standard Specification for Glazing and Glazing Systems Subject to Airblast Loadings*

Blast test standards describe the type of test, shock-tube or arena, the test site, apparatus and instrumentation, the specimen requirements and performance criteria. Both test methods and types of blast testing use a chamber with witness panel that is set behind the sample in which the glass shards may fly or fall during the test. The floor of this chamber and the witness panel are used to determine the hazard rating of the tested assembly. Both of these documents have recommended overpressure and impulse loads and rate the glass particles from the glazing at various hazard levels depending upon the amount, size and impact location of the glass particles. Ratings range from "no" hazard to "high" hazard. The test methods do not include or specify the blast requirements; overpressure, duration, impulse, or required hazard level. These requirements must come from the test sponsor or specifying authority based on the project specifications.

ASTM F1642 sets forth procedures for the evaluation of hazards of glazing or glazing systems against air-blast loadings. This test method allows for glazing to be tested and rated with or without framing systems and is designed to test and rate all glazing, glazing systems, and glazing retrofit systems including, but not limited to, those fabricated from glass, plastic, glass-clad plastics, laminated glass, glass/plastic glazing materials, film- backed glass and non-attached systems. Dynamic test results in accordance with ASTM F1642 are defined by five hazard ratings in accordance with ASTM F2912 (see Figure 1). ASTM F2912 also specifies a minimum of three identical test specimens to comply and provides ranges in window sizes the tested system can qualify.

GSA-TS01 is intended to ensure an adequate measure of standardization and quality assurance in the testing of window systems including but not limited to glazing, sealants, seats and seals, frames, anchorages and all attachments and/or secondary catcher or restraint mechanisms designed to mitigate the hazards from flying glass and debris. This standard is the sole test protocol by which blast resistant windows and related hazard mitigation technology and products shall be evaluated for facilities under the control and responsibility of the US General Services Administration (GSA). This test method has been adopted by the Interagency Security Committee (ISC). There are five GSA building classifications A through E and six performance conditions illustrated in Figure 1.



	Hazard Levels			
DoD LOP	UK (Old)	GSA/ISC	DoS	F1642, UK, & DoD
Very Low	Low Hazard	4 & 3b	4	Low Hazard
Low	Minimal Hazard	3a	3	Very Low Hazard
Medium	Minimal Hazard	2	2	Minimal Hazard
High	No Break	1	1	No Break & No Hazard

Figure 1. ASTM Hazard Levels and GSA/ISC performance conditions for window system response.

UFC 4-010-01

The Unified Facilities Criteria (UFC) Department of Defense (DoD) Minimum Antiterrorism Standards for Buildings provides guidelines set in 21 standards for ALL DoD buildings. It should be noted carefully that this is the minimum standard and higher standards may apply depending on specific conditions.

Section B-3.1 Standard 10 *Windows and Skylights* give minimum standards of construction. A minimum 0.030" PVB interlayer is specified and is typically used within a minimum of ¼" laminated glass. This glass should glazed with a 3/8" minimum bite if installed with a structural silicone or glazed with a minimum of 1" bite if dry glazed. If insulating glass is required the laminated glass must be the inboard lite. This document also gives minimum standards for window framing and anchoring.

Alternative window treatments, such as fragment retention film and blast curtains, may not be used for any DoD buildings required to comply with the standards, but may be used for other situations provided they meet the necessary hazard levels (or levels of protection) and are maintained in accordance with the manufacturers' recommendations. Compliance is demonstrated through analysis or through testing.

Test Reports

Blast testing is performed using controlled practices and very rigid safety guidelines. There are several laboratories throughout North America that are capable of administering these tests. Test reports in accordance with the ASTM or GSA test standards can be requested from glazing materials suppliers, fabricators and systems manufacturers.

Certification Programs

The American Architectural Manufacturers Association[1] (AAMA) offers an AAMA Licensed Security Fenestration Rating and Certification Program based on the AAMA 510-06 *Voluntary Guide Specification for Blast Hazard Mitigation for Fenestration Systems* and administered by Intertek.[2]

Additional Resources

For additional information, please see the following GANA resources:

GANA Laminated Glazing Reference Manual (LGRM) GANA Protective Glazing Manual

Conclusion

The performance of a blast resistant system will vary based on a number of factors, including frame design, anchorage, glazing geometry and details, glass type and thickness, interlayer type and thickness, and applied film type and thickness.

Glazing products can be designed to mitigate damage to property and injury to building occupants in the event of a blast. Blast protection requirements can vary depending on the end-use customer, explosive threat levels, and required level of protection, and there are different glazing design and retrofit approaches that can be employed. Additionally, there are several acceptable approaches to verify the performance of blast resistant glazing. Large scale arena and shock tube testing have shown that glazing can withstand commonly specified performance requirements. Test reports and certifications are available from the manufacturers and component suppliers. In addition, blast design calculations can be performed using simplified to high-fidelity analysis methods to supplement test reports or as independent submittals. Contact the manufacturers and/or component suppliers for more information on achieved performance levels through testing or analysis.

1 American Architectural Manufacturers Association, 1827 Walden Office Square, Suite 550, Schaumburg, IL 60173-4268 United States, Phone: 847.303.5664; Website: www.aamanet.org

2 Architectural Testing, Inc., 130 Derry Court, York, PA 17406-8405 United States, Phone: 717.764.7700; Website: http://www.archtest.com

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