Dynamic Response of Glass Panels subjected to Shock Loading

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Abstract

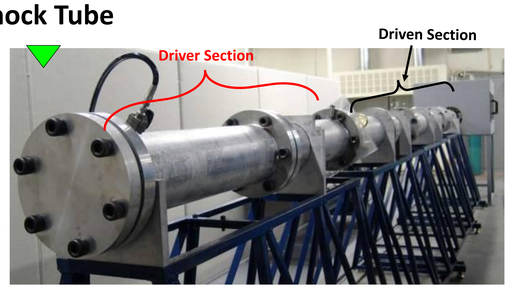
The main objective of this research is to conduct fundamental experiments to elucidate physical mechanisms responsible for damage in novel composite materials & structures subjected to extreme environments associated with blast & fragment loading, thus leading to new more efficient materials & structures with excellent blast mitigation capabilities to safeguard human life and property.

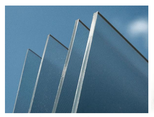
Relevance

Accidental explosions or bomb blasts cause extreme loading on glass structures. This results in the shattering of glass panels into small pieces which have sharp edges and move at very high velocities. These high velocity glass fragments are the major cause of injuries to people. Apart from this, the blast pressure entering the building through the shattered window panels can also cause additional injuries to the occupants. Previously, the main focus of research in this area has been on the numerical/theoretical analysis of glass panels subjected to an explosion. Recently, experimental studies have been done on glass panels to analyze their blast mitigation properties. However, these experiments used either an indenter or an impactor to simulate the blast condition. The aim of this study was to analyze the damaged area, midpoint transient deflection, and other characteristics of the dynamic response of glass panels subjected to a controlled blast loading.

Technical Approach

Shock Tube

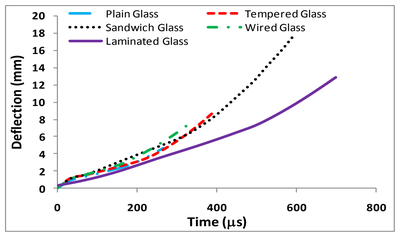


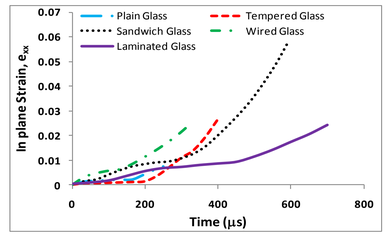

Plane Glass Panel


Sandwiched Glass Panel

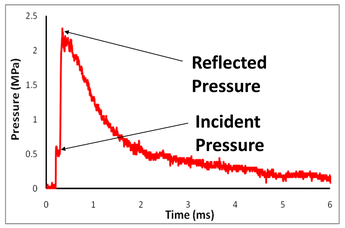

Wired Glass Panel

Laminated Sandwiched Glass Panel

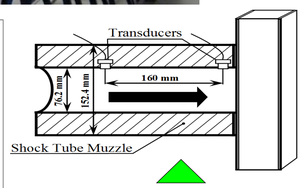




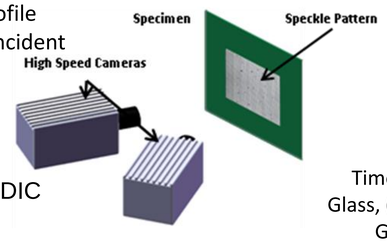
Time-deflection and In-plane history of the back face for five glass panels



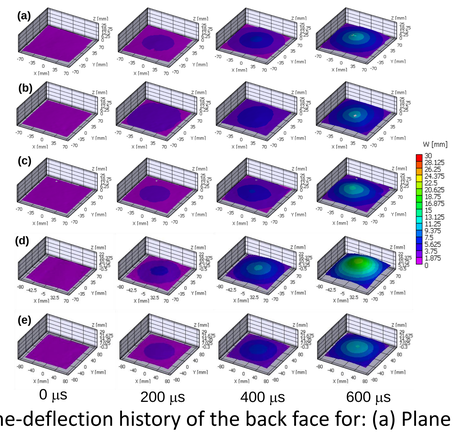
A typical pressure profile showing reflected and incident pressure



Muzzle Detail

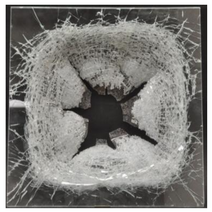


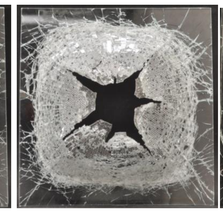
Schematics of 3D DIC system



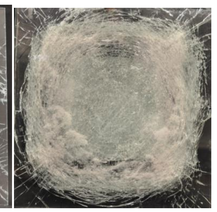
Time-deflection history of the back face for: (a) Plane Glass, (b) Tempered Glass, (c) Wired Glass, (d) Sandwiched Glass, & (e) Laminated Sandwiched Glass Panels

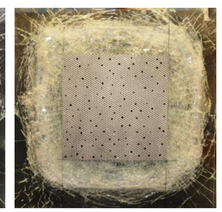
Sandwiched Glass Panel





Laminated Sandwiched Glass Panel





The laminated sandwich glass panel has fragmentation and cracking in the glass panel but the protective film is able to withhold the shattered glass pieces from flying off. There is no through hole formation in the case of the laminated sandwich glass panel which prevents the blast overpressure from entering the building.

Accomplishments Through Current Year

1. A comprehensive series of experiments were conducted under controlled blast loading conditions using the shock tube facility to understand damage mechanisms in structural glass panels. A new type of glass panel was designed which restraints the shattered pieces of glass from flying off and causing damage and injuries.
2. Numerical expressions were developed to understand the energy redistribution associated with shock loading.

Future Work

1. Effect of curvature on blast mitigation property.
2. Effect of face sheet on the blast mitigation property of structure.

Opportunities for Transition to Customer

Consulting with industry

1. 3 Tex, Cary, NC.
2. XO-Armor, Houston, TX.
3. Webcore, OH.
4. TPI Composites, RI.

A new type of glass panel was designed which restraints the shattered pieces of glass from flying off and causing damage and injuries. This development can be accommodated to the existing structures without much difficulty. Technical collaboration with XO-Armor, Texas and PPG Industries will help in this transition. This effort also aligns with the mission of DHS to transition technology and allow for a unified effort to protect our homeland.

Publications Acknowledging DHS Support

- N. Gardner, E. Wang, P. Kumar and A. Shukla, "Blast Mitigation in a Sandwich Composite using Graded Core with Polyurea interlayer" Experimental Mechanics, Accepted for Publication
- E. Wang, N Gardner and A. Shukla, "The blast resistance of sandwich composites with stepwise graded cores", International Journal of Solid and Structures, 46, 3492-3502, 2009.
- E. Wang and A. Shukla, "Analytical and Experimental Evaluation of Energies during Shock Wave Loading", International Journal of Impact Engineering, 37, 1188-1196, 2010.
- M. Jackson and A. Shukla, "Performance of sandwich composites subjected to sequential impact and air blast loading", Composites: Part B (2010), doi:10.1016/j.compositesb.2010.09.005.
- P. Kumar and A. Shukla, "Blast Loading response of Glass Panels", SEM Annual Conference and Exposition, Indianapolis, Indiana, June 7-10, 2010.
- E. Wang and A. Shukla, "Energy and Impulse Evaluation during a Shock Tube Experiment", IMPLAST 2010, SEM Fall Conference, Providence, October 12-14, 2010.
- P. Kumar and A. Shukla, "Dynamic Response of Glass Panels Subjected to Shock Loading", IMPLAST 2010, SEM Fall Conference, Providence, October 12-14, 2010.

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