Extending Glass Façade Performance Predictions for Natural and Man-made Hazards Using Accessible High Fidelity Formulations

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Abstract

Current design approaches for glass hazards generated by natural and man-made insults typically use single degree of freedom (SDOF) methods to analyze the performance of window glazing and mullions. SDOF methods have significant limitations when used for analysis of complex glazing systems such as storefronts and curtain walls. Coupling effects are ignored in SDOF methods, and only single assumed modes of response can be considered. Additionally, more complex support conditions (point supported glass), thermally efficient designs (triple glazed units), and geometrically playful designs (curved glass) are difficult to represent as SDOF systems.

This paper describes the implementation of a statistical glass fracture modeling approach into a "cloud-based" finite element formulation for glass, laminated glass and structural and nonstructural elements (mullions, muntins and connections).

Computational features include advanced user-defined constitutive models (UMATs) that have been implemented in parallel processing structures within the multi-physics finite element code LS-DYNA. These computational features are driven by advanced numerical formulations that include a new Glass Failure Prediction Model (GFPM) based UMAT with an elastic constitutive model with flaw-based probabilistic failure criterion, a new PVB interlayer UMAT, and a new structural silicone LS-DYNA UMAT.

Shock tube tests have been conducted for validation. DIC (digital image correlation) was used for surface displacement measurement in the validation tests. An example of an application to a geometrically and materially complex façade is presented at the conclusion of the paper.

Keywords: high-performance facades, glass hazards, dynamic response, blast loading, impact loading, natural hazards.

1 Introduction

Current glass hazard mitigation design approaches typically use single degree of freedom (SDOF) methods to analyze the performance of window glazing and mullions. The flexural resistance and mass of each component must be identified to define the SDOF representation, and the resistance curve must be calculated based on span, support conditions, cross sectional stiffness, assumed deformed shape, and a failure criterion. SDOF methods have significant limitations when used for analysis of complex glazing systems such as storefronts and curtain walls. The use of FEA can eliminate the assumptions made regarding mass distribution and deformed shape and facilitates spatial fracture prediction at appropriate points on the glass surface. FEA can also ultimately remove SDOF analysis geometry and support restrictions such that analysis can include non-rectilinear and curved or bent glass.

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