INVESTIGATING THE STRUCTURAL RESPONSE OF LAMINATED GLASS PLATES UNDER RIGID BODY IMPACT LOADS

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Thesis/Dissertation submitted in partial fulfilment of the requirements for the degree

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DECLARATION

I declare that this is my own work, and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date: 24/12/2025

The above candidate has carried out research for the PhD/MPhil/Masters thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

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Dr. K. Baskaran

Signature of the Supervisors: Date:

Dr. H. G. H. Damruwan 24/12/2025

24/12/2025

Dr. K. Baskaran

DEDICATION

To my loving parents and little brother. Thank you for your endless love, strength, patience, and constant support. This thesis is a reflection of your faith in me, and I dedicate it to you with all my heart.

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ABSTRACT

Laminated glass (LG) plays a vital role in impact-resistant glazing systems aimed at safeguarding against severe loads from events like hurricanes, windstorms, forced entries, air blasts, and ballistic threats. Nevertheless, our understanding of its resistance to perforation when struck by large rigid missiles is limited, as most research has centred on small missile impacts due to the high cost and complexity of full-scale large rigid body impact testing on LG. Although the response of laminated float glass to impact has been examined, much of this research has concentrated on static or quasi-static parameters. There has been limited exploration into how the rate of loading affects the prediction of LG's impact resistance under dynamic scenarios. Currently, there are no established guidelines for evaluating LG's resistance to rigid projectiles while considering the separate influences of projectile mass, impact velocity, and contact area. This research aims to fill these gaps by calibrating the Johnson-Holmquist Ceramic (JH-2) parameters for LG, utilizing a meta-analysis of existing studies to enhance the precision of impact simulations. A finite element (FE) model is developed to anticipate how LG panels with polyvinyl butyral (PVB) interlayers respond to large missile impacts. This model is validated using experimental data from the literature, carried out in accordance with ASTM standards. The study further develops the numerical model to create perforation vulnerability curves for LG panels based on 270 different impact scenarios. It reveals that increased interlayer thickness improves perforation resistance. Unlike earlier numerical analyses, this work incorporates silicone sealants between glass and aluminium frames, reducing peak stress by more than 90%, delaying stress peaks, redistributing the impact energy, and decreasing the number of cracks at panel edges. Furthermore, it identifies that impact momentum alone is insufficient to predict perforation resistance, emphasizing the separate effects of projectile mass, impact velocity, and projectile contact area. These findings contribute to a structured approach for assessing LG performance under high-strain impact conditions, closing the gap between theoretical and practical applications, and guiding the design of safer, more effective impact-resistant glazing systems.

Keywords: Laminated glass (LG); Johnson-Holmquist ceramic (JH-2) model; Perforation vulnerability curves; Large missile impact; Protective glazing systems; Finite element modelling; Glass fracture mechanics

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
LG	Laminated Glass
PVB	Poly-vinyl Butyral
EVA	Ethylene-vinyl Acetate
FE	Finite Element
JH-2	Johnson-Holmquist Ceramic Model
ASTM	American Society for Testing and Materials
HEL	Hugoniot Elastic Limit
EOS	Equation of State
SPH	Smooth Particle Hydrodynamics
SGP	SentryGlas Plus
CTS	Cyclone Testing Station
AS/NZS	Australian Standard/ New Zealand Standard
SHPB	Split Hopkinson Pressure Bar
MAPE	Mean Absolute Percentage Error
R^2	Coefficient of Determination
RMSE	Root Mean Square Error