Software Requirements Specification for GlassBR

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1 Reference Material

This section records information for easy reference.

1.1 Table of Units

The unit system used throughout is SI (Système International d'Unités). In addition to the basic units, several derived units are also used. For each unit, the Table of Units lists the symbol, a description, and the SI name.

Table 1: Table of Units

Symbol	Description	SI Name
kg	mass	kilogram
m	length	metre
N	force	newton
Pa	pressure	pascal
s	time	second

1.2 Table of Symbols

The symbols used in this document are summarized in the Table of Symbols along with their units. The symbols are listed in alphabetical order.

Table 2: Table of Symbols

Symbol	Description	Units
a	Plate length (long dimension)	m
AR	Aspect ratio	–
AR_{max}	Maximum aspect ratio	–
B	Risk of failure	–
b	Plate width (short dimension)	m
$capacity$	Capacity or load resistance	Pa
d_{max}	Maximum value for one of the dimensions of the glass plate	m
d_{min}	Minimum value for one of the dimensions of the glass plate	m
E	Modulus of elasticity of glass	Pa
g	Glass type	–

Continued on next page

Table 2: Table of Symbols (Continued)

Symbol	Description	Units
GTF	Glass type factor	–
h	Minimum thickness	m
$interpY$	InterpY	–
$interpZ$	InterpZ	–
$isSafeLoad$	Load resistance safety requirement	–
$isSafeLR$	3 second load equivalent resistance safety requirement	–
$isSafePb$	Probability of glass breakage safety requirement	–
$isSafeProb$	Probability of failure safety requirement	–
J	Stress distribution factor (Function)	–
J_{max}	Maximum value for the stress distribution factor	–
J_{min}	Minimum value for the stress distribution factor	–
J_{tol}	Stress distribution factor (Function) based on Pbtol	–
k	Surface flaw parameter	$\frac{\text{m}^{12}}{\text{N}^{7}}$
LDF	Load duration factor	–
$Load$	Applied load (demand) or pressure	Pa
LR	Load resistance	Pa
LSF	Load share factor	–
m	Surface flaw parameter	$\frac{\text{m}^{12}}{\text{N}^{7}}$
NFL	Non-factored load	Pa
P_{b}	Probability of breakage	–
P_{btol}	Tolerable probability of breakage	–
P_{f}	Probability of failure	–
P_{ftol}	Tolerable probability of failure	–
q	Applied load (demand)	Pa
$\hat{q}$	Dimensionless load	–
$\hat{q}_{\text{tol}}$	Tolerable load	–
SD	Stand off distance	m
SD_{max}	Maximum stand off distance permissible for input	m
SD_{min}	Minimum stand off distance permissible for input	m
SD_{x}	Stand off distance (x-component)	m

Continued on next page

Table 2: Table of Symbols (Continued)

Symbol	Description	Units
SD_{y}	Stand off distance (y-component)	m
SD_{z}	Stand off distance (z-component)	m
t	Nominal thickness $t \in \{2.5, 2.7, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 12.0, 16.0, 19.0, 22.0\}$	mm
t_{d}	Duration of load	s
TNT	TNT equivalent factor	–
w	Charge weight	kg
w_{max}	Maximum permissible input charge weight	kg
w_{min}	Minimum permissible input charge weight	kg
w_{TNT}	Equivalent TNT charge mass	kg

1.3 Abbreviations and Acronyms

Table 3: Abbreviations and Acronyms

Abbreviation	Full Form
A	Assumption
AN	Annealed
AR	Aspect Ratio
DD	Data Definition
FT	Fully Tempered
GS	Goal Statement
GTF	Glass Type Factor
HS	Heat Strengthened
IG	Insulating Glass
IM	Instance Model
LC	Likely Change
LDF	Load Duration Factor
LG	Laminated Glass
LR	Load Resistance
LSF	Load Share Factor

Continued on next page

Table 3: Abbreviations and Acronyms (Continued)

Abbreviation	Full Form
N/A	Not Applicable
NFL	Non-Factored Load
PS	Physical System Description
R	Requirement
RefBy	Referenced by
Refname	Reference Name
SD	Stand Off Distance
SRS	Software Requirements Specification
TM	Theoretical Model
UC	Unlikely Change
Uncert.	Typical Uncertainty

2 Introduction

Software is helpful to efficiently and correctly predict the blast risk involved with the glass slab. The blast under consideration is any kind of man-made explosion. The software, herein called GlassBR, aims to predict the blast risk involved with the glass slab using an intuitive interface.

The following section provides an overview of the Software Requirements Specification (SRS) for GlassBR. This section explains the purpose of this document, the scope of the requirements, the characteristics of the intended reader, and the organization of the document.

2.1 Purpose of Document

The primary purpose of this document is to record the requirements of GlassBR. Goals, assumptions, theoretical models, definitions, and other model derivation information are specified, allowing the reader to fully understand and verify the purpose and scientific basis of GlassBR. With the exception of system constraints, this SRS will remain abstract, describing what problem is being solved, but not how to solve it.

This document will be used as a starting point for subsequent development phases, including writing the design specification and the software verification and validation plan. The design document will show how the requirements are to be realized, including decisions on the numerical algorithms and programming environment. The verification and validation plan will show the steps that will be used to increase confidence in the software documentation and the implementation. Although the SRS fits in a series of documents that follow the so-called waterfall model, the actual development process is not constrained in any way. Even when the waterfall model is not followed, as Parnas and Clements point out [7], the most logical way to present the documentation is still to "fake" a rational design process.

2.2 Scope of Requirements

The scope of the requirements includes determining the safety of a glass slab under a blast loading following the ASTM standard ([1]).

2.3 Characteristics of Intended Reader

Reviewers of this documentation should have an understanding of second year calculus, structural mechanics, glass breakage, blast risk, computer applications in civil engineering, and applicable standards for constructions using glass from [1], [3], and [2] in references. The users of GlassBR can have a lower level of expertise, as explained in Sec:User Characteristics.

2.4 Organization of Document

The organization of this document follows the template for an SRS for scientific computing software proposed by [6], [9], [10], and [8]. The presentation follows the standard pattern of presenting goals, theories, definitions, and assumptions. For readers that would like a more bottom up approach, they can start reading the data definitions and trace back to find any additional information they require.

The goal statements are refined to the theoretical models and the theoretical models to the instance models. The data definitions are used to support the definitions of the different models.

3 Stakeholders

This section describes the stakeholders: the people who have an interest in the product.

3.1 The Client

The client for GlassBR is a company named Entuitive. It is developed by Dr. Manuel Campidelli. The client has the final say on acceptance of the product.

3.2 The Customer

The customers are the end user of GlassBR.

Figure 1: System Context

4 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristics, and lists the system constraints.

4.1 System Context

Fig:sysCtxDiag shows the system context. A circle represents an external entity outside the software, the user in this case. A rectangle represents the software system itself (GlassBR). Arrows are used to show the data flow between the system and its environment.

The interaction between the product and the user is through a user interface. The responsibilities of the user and the system are as follows:

- User Responsibilities
  - Provide the input data related to the glass slab and blast type, ensuring no errors in the data entry.
  - Ensure that consistent units are used for input variables.
  - Ensure required software assumptions are appropriate for any particular problem input to the software.
- GlassBR Responsibilities
  - Detect data type mismatch, such as a string of characters input instead of a floating point number.
  - Determine if the inputs satisfy the required physical and software constraints.
  - Predict whether the glass slab is safe or not.

4.2 User Characteristics

- The end user of GlassBR is expected to have completed at least the equivalent of the second year of an undergraduate degree in civil engineering or structural engineering.

- The end user is expected to have an understanding of theory behind glass breakage and blast risk.
- The end user is expected to have basic computer literacy to handle the software.

4.3 System Constraints

There are no system constraints.

5 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, and definitions that are used.

5.1 Problem Description

A system is needed to predict whether a glass slab can withstand a blast under given conditions.

5.1.1 Terminology and Definitions

This subsection provides a list of terms that are used in the subsequent sections and their meaning, with the purpose of reducing ambiguity and making it easier to correctly understand the requirements. All of the terms are extracted from [1].

1. Glass breakage - The fracture or breakage of any lite or ply in monolithic, laminated, or insulating glass.
2. Lateral - Perpendicular to the glass surface.
3. Lite - Pieces of glass that are cut, prepared, and used to create the window or door.
4. Specifying authority - The design professional responsible for interpreting applicable regulations of authorities having jurisdiction and considering appropriate site specific factors to determine the appropriate values used to calculate the specified design load, and furnishing other information required to perform this practice.
5. Blast resistant glazing - Glazing that provides protection against air blast pressure generated by explosions.
6. Equivalent TNT charge mass - Mass of TNT placed on the ground in a hemisphere that represents the design explosive threat.
7. Glass Type:

- Annealed (AN) - A flat, monolithic, glass lite which has uniform thickness where the residual surface stresses are almost zero, as defined in [2].
- Fully tempered (FT) - A flat, monolithic, glass lite of uniform thickness that has been subjected to a special heat treatment process where the residual surface compression is not less than 69 MPa (10 000 psi) or the edge compression not less than 67 MPa (9700 psi), as defined in [3].
- Heat strengthened (HS) - A flat, monolithic, glass lite of uniform thickness that has been subjected to a special heat treatment process where the residual surface compression is not less than 24 MPa (3500psi) or greater than 52 MPa (7500 psi), as defined in [3].

8. Applied load (demand) or pressure - A uniformly distributed lateral pressure.

   - Load resistance (LR) - The uniform lateral load that a glass construction can sustain based upon a given probability of breakage and load duration as defined in [1, (pp. 1 and 53)].
   - Non-factored load (NFL) - Three second duration uniform load associated with a probability of breakage less than or equal to 8 lites per 1000 for monolithic AN glass.
   - Glass weight load - The dead load component of the glass weight.
   - Short duration load - Any load lasting 3 seconds or less.
   - Specified design load - The magnitude in Pa (psf), type (for example, wind or snow) and duration of the load given by the specifying authority.
   - Long duration load - Any load lasting approximately 30 days.

9. Stand off distance (SD) - The distance from the glazing surface to the centroid of a hemispherical high explosive charge. It is represented by the coordinates (SD_{x}, SD_{y}, SD_{z}).

10. Load share factor (LSF) - A multiplying factor derived from the load sharing between the double glazing, of equal or different thicknesses and types (including the layered behaviour of LG under long duration loads), in a sealed IG unit.

11. Glass type factor (GTF) - A multiplying factor for adjusting the LR of different glass type, that is, AN, FT, or HS, in monolithic glass, LG (Laminated Glass), or IG (Insulating Glass) constructions.

12. Aspect ratio (AR) - The ratio of the long dimension of the glass to the short dimension of the glass. For glass supported on four sides, the aspect ratio is always equal to or greater than 1.0. For glass supported on three sides, the ratio of the length of one of the supported edges perpendicular to the free edge, to the length of the free edge, is equal to or greater than 0.5.

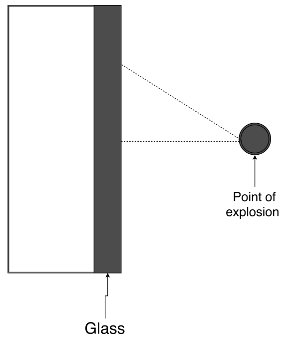

Figure 2: The physical system

13. Probability of breakage (P_{b}) - The fraction of glass lites or plies that would break at the first occurrence of a specified load and duration, typically expressed in lites per 1000 ([2]).

5.1.2 Physical System Description

The physical system of GlassBR, as shown in Fig:physSystImage, includes the following elements:

PS1: The glass slab.

PS2: The point of explosion. Where the bomb, or any kind of man-made explosion, is located. The stand off distance is the distance between the point of explosion and the glass.

5.1.3 Goal Statements

Given the dimensions of the glass plane, the glass type, the characteristics of the explosion, and the tolerable probability of breakage, the goal statement is:

hstands-Explosion: Analyze and predict whether the glass slab under consideration will be able to withstand the explosion of a certain degree which is calculated based on user input.

5.2 Solution Characteristics Specification

The instance models that govern GlassBR are presented in the Instance Model Section. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

5.2.1 Assumptions

This section simplifies the original problem and helps in developing the theoretical models by filling in the missing information for the physical system. The assumptions refine the scope by providing more detail.

glassType: The standard E1300-09a for calculation applies only to monolithic, laminated, or insulating glass constructions of rectangular shape with continuous lateral support along one, two, three, or four edges. This practice assumes that: (1) the supported glass edges for two, three and four-sided support conditions are simply supported and free to slip in plane; (2) glass supported on two sides acts as a simply supported beam; and (3) glass supported on one side acts as a cantilever.

glassCondition: Following [1, (pg. 1)], this practice does not apply to any form of wired, patterned, etched, sandblasted, drilled, notched, or grooved glass with surface and edge treatments that alter the glass strength. (RefBy: UC:Accommodate-Altered-Glass.)

explainScenario: This system only considers the external explosion scenario for its calculations. (RefBy: LC:Calculate-Internal-Blast-Risk.)

standardValues: The values provided in Sec:Values of Auxiliary Constants are assumed for the duration of load (t_{d}), and the material properties of m, k, and E. (RefBy: LC:Variable-Values-of-m,k,E, IM:sdfTol, IM:nFL, DD:loadDurFactor, IM:dimlessLoad, and A:ldf-Constant.)

glassLite: Glass under consideration is assumed to be a single lite; hence, the value of LSF is equal to 1 for all calculations in GlassBR. (RefBy: LC:Accomodate-More-than-Single-Lite.)

oundaryConditions: Boundary conditions for the glass slab are assumed to be 4-sided support for calculations. (RefBy: LC:Accomodate-More-Boundary-Conditions.)

responseType: The response type considered in GlassBR is flexural. (RefBy: LC:Consider-More-than-Flexure-Glass.)

ldfConstant: With reference to A:standardValues, the value of load duration factor (LDF) is a constant in GlassBR. (RefBy: LC:Variable-Values-of-m,k,E and DD:loadDurFactor.)

5.2.2 Theoretical Models

This section focuses on the general equations and laws that GlassBR is based on.

Refname	**TM:isSafeProb**
Label	Safety Probability
Equation	$$isSafeProb = P_{\text{f}} < P_{\text{ftol}}$$
Description	$isSafeProb$ is the probability of failure safety requirement (Unitless) P_{f} is the probability of failure (Unitless) P_{ftol} is the tolerable probability of failure (Unitless)
Notes	If $isSafeProb$, the structure is considered safe.
Source	[1]
RefBy	

Refname	**TM:isSafeLoad**
Label	Safety Load
Equation	$$isSafeLoad = capacity > Load$$
Description	$isSafeLoad$ is the load resistance safety requirement (Unitless) $capacity$ is the capacity or load resistance (Pa) $Load$ is the applied load (demand) or pressure (Pa)
Notes	If $isSafeLoad$, the structure is considered safe.
Source	[1]
RefBy	

5.2.3 General Definitions

There are no general definitions.

5.2.4 Data Definitions

This section collects and defines all the data needed to build the instance models.

Refname	**DD:minThick**
Label	Minimum thickness
Symbol	h
Units	m
Equation	$$h = \frac{1}{1000}\begin{cases} 2.16, & t = 2.5 \\ 2.59, & t = 2.7 \\ 2.92, & t = 3.0 \\ 3.78, & t = 4.0 \\ 4.57, & t = 5.0 \\ 5.56, & t = 6.0 \\ 7.42, & t = 8.0 \\ 9.02, & t = 10.0 \\ 11.91, & t = 12.0 \\ 15.09, & t = 16.0 \\ 18.26, & t = 19.0 \\ 21.44, & t = 22.0 \end{cases}$$
Description	h is the minimum thickness (m) t is the nominal thickness $t \in \{2.5, 2.7, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 12.0, 16.0, 19.0, 22.0\}$ (mm)
Notes	t is a function that maps from the nominal thickness (h) to the minimum thickness.
Source	[1]
RefBy	IM:sdfTol, IM:riskFun, IM:nFL, and IM:dimlessLoad

Refname	**DD:loadDurFactor**
Label	Load duration factor
Symbol	LDF
Units	Unitless
Equation	$$LDF = \left(\frac{t_{\text{d}}}{60}\right)^{\frac{m}{16}}$$
Description	LDF is the load duration factor (Unitless) t_{d} is the duration of load (s) m is the surface flaw parameter ($\frac{\text{m}^{12}}{\text{N}^{7}}$)
Notes	t_{d} and m come from A:standardValues. LDF is assumed to be constant (from A:ldfConstant).
Source	[1]
RefBy	IM:sdfTol and IM:riskFun

Refname	DD:gTF
Label	Glass type factor
Symbol	GTF
Units	Unitless
Equation	$$GTF = \begin{cases} 1, & g = \text{"AN"} \\ 4, & g = \text{"FT"} \\ 2, & g = \text{"HS"} \end{cases}$$
Description	GTF is the glass type factor (Unitless) g is the glass type (Unitless)
Notes	AN is annealed glass. FT is fully tempered glass. HS is heat strengthened glass.
Source	[1]
RefBy	IM:calofCapacity and IM:dimlessLoad

Refname	**DD:standOffDist**
Label	Stand off distance
Symbol	SD
Units	m
Equation	$$SD = \sqrt{{SD_{\text{x}}}^{2} + {SD_{\text{y}}}^{2} + {SD_{\text{z}}}^{2}}$$
Description	SD is the stand off distance (m) SD_{x} is the stand off distance (x-component) (m) SD_{y} is the stand off distance (y-component) (m) SD_{z} is the stand off distance (z-component) (m)
Source	[1]
RefBy	DD:calofDemand

Refname	**DD:aspectRatio**
Label	Aspect ratio
Symbol	AR
Units	Unitless
Equation	$$AR = \frac{a}{b}$$
Description	AR is the aspect ratio (Unitless) a is the plate length (long dimension) (m) b is the plate width (short dimension) (m)
Notes	a and b are the dimensions of the plate, where $(a \geq b)$.
Source	[1]
RefBy	IM:tolLoad and IM:stressDistFac

Refname	DD:eqTNTW
Label	Equivalent TNT charge mass
Symbol	w_{TNT}
Units	kg
Equation	$$w_{TNT} = wTNT$$
Description	w_{TNT} is the equivalent TNT charge mass (kg) w is the charge weight (kg) TNT is the TNT equivalent factor (Unitless)
Source	[1]
RefBy	DD:calofDemand

Refname	DD:calofDemand
Label	Applied load (demand)
Symbol	q
Units	Pa
Equation	$$q = interpY\left(\text{“TSD.txt”}, SD, w_{TNT}\right)$$
Description	q is the applied load (demand) (Pa) $interpY$ is the interpY (Unitless) SD is the stand off distance (m) w_{TNT} is the equivalent TNT charge mass (kg)
Notes	q, or applied load (demand), is the 3 second duration equivalent pressure obtained from Fig:demandVSsod by interpolation using stand off distance (SD) and w_{TNT} as parameters. w_{TNT} is defined in DD:eqTNTW. SD is the stand off distance as defined in DD:standOffDist.
Source	[1]
RefBy	IM:isSafeLR and IM:dimlessLoad

5.2.5 Instance Models

This section transforms the problem defined in the problem description into one which is expressed in mathematical terms. It uses concrete symbols defined in the data definitions to replace the abstract symbols in the models identified in theoretical models and general definitions.

The goal GS:Predict-Glass-Withstands-Explosion is met by IM:isSafePb, IM:isSafeLR.

Refname	**IM:riskFun**
Label	Risk of failure
Input	E, LDF, J, k, m, h, a, b
Output	B
Input Constraints	$$a > 0$$ $$0 < b \leq a$$
Output Constraints	
Equation	$$B = \frac{k}{(ab)^{m-1}} \left(Eh^2\right)^m LDFe^J$$
Description	B is the risk of failure (Unitless) k is the surface flaw parameter ($\frac{\mathrm{m}^{12}}{\mathrm{N}^7}$) a is the plate length (long dimension) (m) b is the plate width (short dimension) (m) m is the surface flaw parameter ($\frac{\mathrm{m}^{12}}{\mathrm{N}^7}$) E is the modulus of elasticity of glass (Pa) h is the minimum thickness (m) LDF is the load duration factor (Unitless) J is the stress distribution factor (Function) (Unitless)
Notes	a and b are the dimensions of the plate, where $(a \geq b)$. h is defined in DD:minThick and is based on the nominal thicknesses. LDF is defined in DD:loadDurFactor. J is defined in IM:stressDistFac.
Source	[1], [4, (Eqs. 4-5)], and [5, (Eq. 14)]
RefBy	IM:probOfBreak

Refname	IM:stressDistFac
Label	Stress distribution factor (Function)
Input	AR, $\hat{q}$
Output	J
Input Constraints	$$AR \geq 1$$
Output Constraints	$$J_{\text{min}} \leq J \leq J_{\text{max}}$$
Equation	$$J = \mathit{interpZ}\left(\text{“SDF.txt”}, AR, \hat{q}\right)$$
Description	J is the stress distribution factor (Function) (Unitless) $\mathit{interpZ}$ is the interpZ (Unitless) AR is the aspect ratio (Unitless) $\hat{q}$ is the dimensionless load (Unitless)
Notes	J is obtained by interpolating from data shown in Fig:dimlessloadVSaspect. AR is defined in DD:aspectRatio. $\hat{q}$ is defined in IM:dimlessLoad.
Source	[1]
RefBy	IM:riskFun

Refname	**IM:nFL**
Label	Non-factored load
Input	$\hat{q}_{\text{tol}}$, E, h, a, b
Output	NFL
Input Constraints	$$a > 0$$ $$0 < b \leq a$$
Output Constraints	
Equation	$$NFL = \frac{\hat{q}_{\text{tol}} E h^4}{(ab)^2}$$
Description	NFL is the non-factored load (Pa) $\hat{q}_{\text{tol}}$ is the tolerable load (Unitless) E is the modulus of elasticity of glass (Pa) h is the minimum thickness (m) a is the plate length (long dimension) (m) b is the plate width (short dimension) (m)
Notes	$\hat{q}_{\text{tol}}$ is defined in IM:tolLoad. E comes from A:standardValues. h is defined in DD:minThick and is based on the nominal thicknesses. a and b are the dimensions of the plate, where $(a \geq b)$.
Source	[1]
RefBy	IM:calofCapacity

Refname	IM:dimlessLoad
Label	Dimensionless load
Input	q, E, h, GTF, a, b
Output	$\hat{q}$
Input Constraints	$$a > 0$$ $$0 < b \leq a$$
Output Constraints	
Equation	$$\hat{q} = \frac{q\,(ab)^2}{Eh^4\,GTF}$$
Description	$\hat{q}$ is the dimensionless load (Unitless) q is the applied load (demand) (Pa) a is the plate length (long dimension) (m) b is the plate width (short dimension) (m) E is the modulus of elasticity of glass (Pa) h is the minimum thickness (m) GTF is the glass type factor (Unitless)
Notes	q is the 3 second duration equivalent pressure, as given in DD:calofDemand. a and b are the dimensions of the plate, where ($a \geq b$). E comes from A:standardValues. h is defined in DD:minThick and is based on the nominal thicknesses. GTF is defined in DD:gTF.
Source	[1] and [5, (Eq. 7)]
RefBy	IM:stressDistFac

Refname	IM:tolLoad
Label	Tolerable load
Input	AR, J_{tol}
Output	$\hat{q}_{\text{tol}}$
Input Constraints	$$AR \geq 1$$
Output Constraints	
Equation	$$\hat{q}_{\text{tol}} = interpY\left(\text{“SDF.txt”}, AR, J_{\text{tol}}\right)$$
Description	$\hat{q}_{\text{tol}}$ is the tolerable load (Unitless) $interpY$ is the interpY (Unitless) AR is the aspect ratio (Unitless) J_{tol} is the stress distribution factor (Function) based on Pbtol (Unitless)
Notes	$\hat{q}_{\text{tol}}$ is obtained by interpolating from data shown in Fig:dimlessloadVSaspect. AR is defined in DD:aspectRatio. J_{tol} is defined in IM:sdfTol.
Source	[1]
RefBy	IM:nFL

Refname	IM:sdfTol
Label	Stress distribution factor (Function) based on Pbtol
Input	LDF, P_{btol}, E, a, b, m, k, h
Output	J_{tol}
Input Constraints	$0 \leq P_{\text{btol}} \leq 1$ $a > 0$ $0 < b \leq a$
Output Constraints	
Equation	$J_{\text{tol}} = \ln\left(\ln\left(\frac{1}{1-P_{\text{btol}}}\right)\frac{(ab)^{m-1}}{k\left(Eh^2\right)^m LDF}\right)$
Description	J_{tol} is the stress distribution factor (Function) based on Pbtol (Unitless) P_{btol} is the tolerable probability of breakage (Unitless) a is the plate length (long dimension) (m) b is the plate width (short dimension) (m) m is the surface flaw parameter ($\frac{\text{m}^{12}}{\text{N}^7}$) k is the surface flaw parameter ($\frac{\text{m}^{12}}{\text{N}^7}$) E is the modulus of elasticity of glass (Pa) h is the minimum thickness (m) LDF is the load duration factor (Unitless)
Notes	P_{btol} is entered by the user. a and b are the dimensions of the plate, where ($a \geq b$). m, k, and E come from A:standardValues. h is defined in DD:minThick and is based on the nominal thicknesses. LDF is defined in DD:loadDurFactor.
Source	[1]
RefBy	IM:tolLoad

Refname	IM:probOfBreak
Label	Probability of breakage
Input	B
Output	P_{b}
Input Constraints	
Output Constraints	$$0 \leq P_{\text{b}} \leq 1$$
Equation	$$P_{\text{b}} = 1 - e^{-B}$$
Description	P_{b} is the probability of breakage (Unitless) B is the risk of failure (Unitless)
Notes	B is defined in IM:riskFun.
Source	[1] and [4]
RefBy	IM:isSafePb

Refname	IM:calofCapacity
Label	Load resistance
Input	NFL, GTF, LSF
Output	LR
Input Constraints	
Output Constraints	
Equation	$$LR = NFL GTF LSF$$
Description	LR is the load resistance (Pa) NFL is the non-factored load (Pa) GTF is the glass type factor (Unitless) LSF is the load share factor (Unitless)
Notes	LR is also called capacity. NFL is defined in IM:nFL. GTF is defined in DD:gTF.
Source	[1]
RefBy	IM:isSafeLR

Refname	**IM:isSafePb**
Label	Safety Req-Pb
Input	P_{b}, P_{btol}
Output	$isSafePb$
Input Constraints	$$0 \leq P_{\text{b}} \leq 1$$ $$0 \leq P_{\text{btol}} \leq 1$$
Output Constraints	
Equation	$$isSafePb = P_{\text{b}} < P_{\text{btol}}$$
Description	$isSafePb$ is the probability of glass breakage safety requirement (Unitless) P_{b} is the probability of breakage (Unitless) P_{btol} is the tolerable probability of breakage (Unitless)
Notes	If $isSafePb$, the glass is considered safe. $isSafePb$ and $isSafeLR$ (from IM:isSafeLR) are either both True or both False. P_{b} is defined in IM:probOfBreak. P_{btol} is entered by the user.
Source	[1]
RefBy	IM:isSafeLR and FR:Check-Glass-Safety

Refname	IM:isSafeLR
Label	Safety Req-LR
Input	LR, q
Output	$isSafeLR$
Input Constraints	$$LR > 0$$ $$q > 0$$
Output Constraints	
Equation	$$isSafeLR = LR > q$$
Description	$isSafeLR$ is the 3 second load equivalent resistance safety requirement (Unitless) LR is the load resistance (Pa) q is the applied load (demand) (Pa)
Notes	If $isSafeLR$, the glass is considered safe. $isSafePb$ (from IM:isSafePb) and $isSafeLR$ are either both True or both False. LR is defined in IM:calofCapacity and is also called capacity. q is the 3 second duration equivalent pressure, as given in DD:calofDemand.
Source	[1]
RefBy	IM:isSafePb and FR:Check-Glass-Safety

5.2.6 Data Constraints

The Data Constraints Table shows the data constraints on the input variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable. The uncertainty column provides an estimate of the confidence with which the physical quantities can be measured. This information would be part of the input if one were performing an uncertainty quantification exercise. The constraints are conservative to give the user of the model the flexibility to experiment with unusual situations. The column of typical values is intended to provide a feel for a common scenario. The auxiliary constants give the values of the specification parameters used in the Data Constraints Table.

Table 4: Input Data Constraints

Var	Physical Constraints	Software Constraints	Typical Value	Uncert.
a	$a > 0 \land a \geq b$	$d_{\text{min}} \leq a \leq d_{\text{max}}$	1.5 m	10%
AR	$AR \geq 1$	$AR \leq AR_{\text{max}}$	1.5	10%
b	$0 < b \leq a$	$d_{\text{min}} \leq b \leq d_{\text{max}}$	1.2 m	10%
P_{btol}	$0 \leq P_{\text{btol}} \leq 1$	–	0.008	0.1%
SD	$SD > 0$	$SD_{\text{min}} \leq SD \leq SD_{\text{max}}$	45 m	10%
TNT	$TNT > 0$	–	1	10%
w	$w > 0$	$w_{\text{min}} \leq w \leq w_{\text{max}}$	42 kg	10%

5.2.7 Properties of a Correct Solution

The Data Constraints Table shows the data constraints on the output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable.

Table 5: Output Data Constraints

Var	Physical Constraints
P_{b}	$0 \leq P_{\text{b}} \leq 1$
J	$J_{\text{min}} \leq J \leq J_{\text{max}}$

6 Requirements

This section provides the functional requirements, the tasks and behaviours that the software is expected to complete, and the non-functional requirements, the qualities that the software is expected to exhibit.

6.1 Functional Requirements

This section provides the functional requirements, the tasks and behaviours that the software is expected to complete.

Input-Values: Input the values from Tab:ReqInputs, which define the glass dimensions, type of glass, tolerable probability of failure, and the characteristics of the blast.

wing-Assumptions: The system shall set the known values as described in the table for Required Assignments.

Data_Constraints: The system shall check the entered input values to ensure that they do not exceed the data constraints. If any of the input values are out of bounds, an error message is displayed and the calculations stop.

nd-Known-Values: Output the input values from FR:Input-Values and the known values from FR:System-Set-Values-Following-Assumptions.

heck-Glass-Safety: If $isSafePb \wedge isSafeLR$ (from IM:isSafePb and IM:isSafeLR), output the message "For the given input parameters, the glass is considered safe." If the condition is false, then output the message "For the given input parameters, the glass is NOT considered safe."

Output-Values: Output the values from the table for Required Outputs.

Table 6: Required Inputs following FR:Input-Values

Symbol	Description	Units
a	Plate length (long dimension)	m
b	Plate width (short dimension)	m
g	Glass type	–
P_{btol}	Tolerable probability of breakage	–
SD_{x}	Stand off distance (x-component)	m
SD_{y}	Stand off distance (y-component)	m
SD_{z}	Stand off distance (z-component)	m
t	Nominal thickness $t \in \{2.5, 2.7, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 12.0, 16.0, 19.0, 22.0\}$	mm
TNT	TNT equivalent factor	–
w	Charge weight	kg

Table 7: Required Assignments following FR:System-Set-Values-Following-Assumptions

Symbol	Description	Source	Units
AR	Aspect ratio	DD:aspectRatio	–
E	Modulus of elasticity of glass	A:standardValues	Pa
GTF	Glass type factor	DD:gTF	–
h	Minimum thickness	DD:minThick	m
k	Surface flaw parameter	A:standardValues	$\frac{\mathrm{m}^{12}}{\mathrm{N}^{7}}$
LDF	Load duration factor	DD:loadDurFactor	–
LSF	Load share factor	A:glassLite	–
m	Surface flaw parameter	A:standardValues	$\frac{\mathrm{m}^{12}}{\mathrm{N}^{7}}$
SD	Stand off distance	DD:standOffDist	m
t_{d}	Duration of load	A:standardValues	s

Table 8: Required Outputs following FR:Output-Values

Symbol	Description	Source	Units
AR	Aspect ratio	DD:aspectRatio	–
B	Risk of failure	IM:riskFun	–
GTF	Glass type factor	DD:gTF	–
h	Minimum thickness	DD:minThick	m
$isSafeLR$	Safety Req-LR	IM:isSafeLR	–
$isSafePb$	Safety Req-Pb	IM:isSafePb	–
J	Stress distribution factor (Function)	IM:stressDistFac	–
J_{tol}	Stress distribution factor (Function) based on Pbtol	IM:sdfTol	–
LR	Load resistance	IM:calofCapacity	Pa
NFL	Non-factored load	IM:nFL	Pa
P_{b}	Probability of breakage	IM:probOfBreak	–
$\hat{q}$	Dimensionless load	IM:dimlessLoad	–
$\hat{q}_{\mathrm{tol}}$	Tolerable load	IM:tolLoad	–

6.2 Non-Functional Requirements

This section provides the non-functional requirements, the qualities that the software is expected to exhibit.

Correct: The outputs of the code have the properties described in Sec:Properties of a Correct Solution.

Verifiable: The code is tested with complete verification and validation plan.

Understandable: The code is modularized with complete module guide and module interface specification.

Reusable: The code is modularized.

Maintainable: The traceability between requirements, assumptions, theoretical models, general definitions, data definitions, instance models, likely changes, unlikely changes, and modules is completely recorded in traceability matrices in the SRS and module guide.

Portable: The code is able to be run in different environments.

7 Likely Changes

This section lists the likely changes to be made to the software.

nternal-Blast-Risk: A:explainScenario - The system currently only calculates for external blast risk. In the future, calculations can be added for the internal blast risk.

le-Values-of-m,k,E: A:standardValues, A:ldfConstant - Currently, the values for m, k, and E are assumed to be the same for all glass. In the future, these values can be changed to variable inputs.

re-than-Single-Lite: A:glassLite - The software may be changed to accommodate more than a single lite.

undary-Conditions: A:boundaryConditions - The software may be changed to accommodate more boundary conditions than 4-sided support.

han-Flexure-Glass: A:responseType - The software may be changed to consider more than just flexure of the glass.

8 Unlikely Changes

This section lists the unlikely changes to be made to the software.

-of-Certain-Degree: The goal of the system is to predict whether the glass slab under consideration can withstand an explosion of a certain degree.

date-Altered-Glass: A:glassCondition requires that the glass is not altered in any way. Therefore, this cannot be used on altered glass.

9 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time a component is changed, the items in the column of that component that are marked with an "X" should be modified as well. Tab:TraceMatAvsA shows the dependencies of the assumptions on each other. Tab:TraceMatAvsAll shows the dependencies of the data definitions, theoretical models, general definitions, instance models, requirements, likely changes, and unlikely changes on the assumptions. Tab:TraceMatRefvsRef shows the dependencies of the data definitions, theoretical models, general definitions, and instance models on each other. Tab:TraceMatAllvsR shows the dependencies of the requirements and goal statements on the data definitions, theoretical models, general definitions, and instance models.

Table 9: Traceability Matrix Showing the Connections Betw

	A:glassType	**A:glassCondition**	**A:explainScenario**	**A:standardValu**
A:glassType				
A:glassCondition				
A:explainScenario				
A:standardValues				
A:glassLite				
A:boundaryConditions				
A:responseType				
A:ldfConstant				X

Table 10: Traceability Matrix Showing the Co

	A:glassType	**A:glassCondition**	**A:explainScenar**
DD:minThick			
DD:loadDurFactor			
DD:gTF			
DD:standOffDist			
DD:aspectRatio			

Table 10: Traceability Matrix Showing the Connecti

	A:glassType	A:glassCondition	A:explainScenar
DD:eqTNTW			
DD:calofDemand			
TM:isSafeProb			
TM:isSafeLoad			
IM:riskFun			
IM:stressDistFac			
IM:nFL			
IM:dimlessLoad			
IM:tolLoad			
IM:sdfTol			
IM:probOfBreak			
IM:calofCapacity			
IM:isSafePb			
IM:isSafeLR			
FR:Input-Values			
FR:System-Set-Values-Following-Assumptions			
FR:Check-Input-with-Data_Constraints			
FR:Output-Values-and-Known-Values			
FR:Check-Glass-Safety			
FR:Output-Values			
NFR:Correct			
NFR:Verifiable			
NFR:Understandable			
NFR:Reusable			
NFR:Maintainable			
NFR:Portable			
LC:Calculate-Internal-Blast-Risk			X
LC:Variable-Values-of-m,k,E			
LC:Accomodate-More-than-Single-Lite			
LC:Accomodate-More-Boundary-Conditions			

Table 10: Traceability Matrix Showing the Connecti

	A:glassType	A:glassCondition	A:explainScenar
LC:Consider-More-than-Flexure-Glass			
UC:Predict-Withstanding-of-Certain-Degree			
UC:Accommodate-Altered-Glass		X	

	DD:minThick	DD:loadDurFactor	DD:gTF	DD:standOffDist	DD:asp
DD:minThick					
DD:loadDurFactor					
DD:gTF					
DD:standOffDist					
DD:aspectRatio					
DD:eqTNTW					
DD:calofDemand				X	
TM:isSafeProb					
TM:isSafeLoad					
IM:riskFun	X	X			
IM:stressDistFac					X
IM:nFL	X				
IM:dimlessLoad	X		X		
IM:tolLoad					X
IM:sdfTol	X	X			
IM:probOfBreak					
IM:calofCapacity			X		
IM:isSafePb					
IM:isSafeLR					

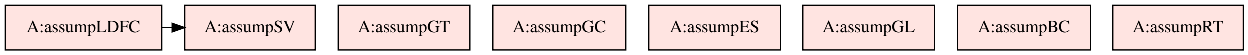

Figure 3: TraceGraphAvsA

	DD:minThick	**DD:loadDurFactor**	**DD:gTF**	**D**
GS:Predict-Glass-Withstands-Explosion				
FR:Input-Values				
FR:System-Set-Values-Following-Assumptions				
FR:Check-Input-with-Data_Constraints				
FR:Output-Values-and-Known-Values				
FR:Check-Glass-Safety				
FR:Output-Values				
NFR:Correct				
NFR:Verifiable				
NFR:Understandable				
NFR:Reusable				
NFR:Maintainable				
NFR:Portable				

The purpose of the traceability graphs is also to provide easy references on what has to be additionally modified if a certain component is changed. The arrows in the graphs represent dependencies. The component at the tail of an arrow is depended on by the component at the head of that arrow. Therefore, if a component is changed, the components that it points to should also be changed. Fig:TraceGraphAvsA shows the dependencies of assumptions on each other. Fig:TraceGraphAvsAll shows the dependencies of data definitions, theoretical models, general definitions, instance models, requirements, likely changes, and unlikely changes on the assumptions. Fig:TraceGraphRefvsRef shows the dependencies of data definitions, theoretical models, general definitions, and instance models on each other. Fig:TraceGraphAllvsR shows the dependencies of requirements and goal statements on the data definitions, theoretical models, general definitions, and instance models. Fig:TraceGraphAllvsAll shows the dependencies of dependencies of assumptions, models, definitions, requirements, goals, and changes with each other.

For convenience, the following graphs can be found at the links below:

- TraceGraphAvsA

Figure 4: TraceGraphAvsAll

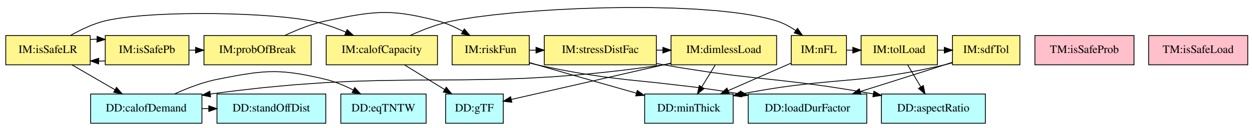

Figure 5: TraceGraphRefvsRef

- TraceGraphAvsAll
- TraceGraphRefvsRef
- TraceGraphAllvsR
- TraceGraphAllvsAll

10 Values of Auxiliary Constants

This section contains the standard values that are used for calculations in GlassBR.

Table 13: Auxiliary Constants

Symbol	Description	Value	Unit
AR_{max}	maximum aspect ratio	5	–
d_{max}	maximum value for one of the dimensions of the glass plate	5	m
d_{min}	minimum value for one of the dimensions of the glass plate	0.1	m
E	modulus of elasticity of glass	$71.7 \cdot 10^{9}$	Pa
J_{max}	maximum value for the stress distribution factor	32	–
J_{min}	minimum value for the stress distribution factor	1	–

Continued on next page

Figure 6: TraceGraphAllvsR

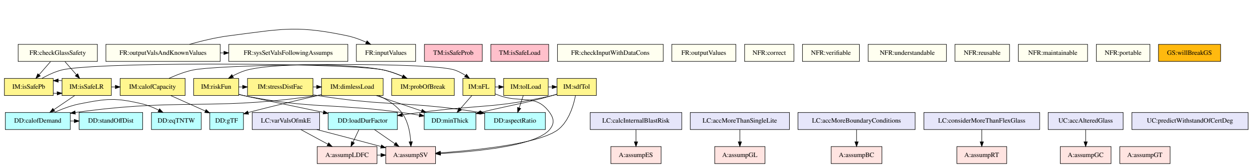

Figure 7: TraceGraphAllvsAll

Table 13: Auxiliary Constants (Continued)

Symbol	Description	Value	Unit
k	surface flaw parameter	$28.6 \cdot 10^{-54}$	$\frac{\text{m}^{12}}{\text{N}^{7}}$
LSF	load share factor	1	–
m	surface flaw parameter	7	$\frac{\text{m}^{12}}{\text{N}^{7}}$
SD_{max}	maximum stand off distance permissible for input	130	m
SD_{min}	minimum stand off distance permissible for input	6	m
t_{d}	duration of load	3	s
w_{max}	maximum permissible input charge weight	910	kg
w_{min}	minimum permissible input charge weight	4.5	kg

11 References

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[7] David L. Parnas and P. C. Clements. "A rational design process: How and why to fake it". In: *IEEE Transactions on Software Engineering* 12.2 (Feb. 1986), pp. 251–257.

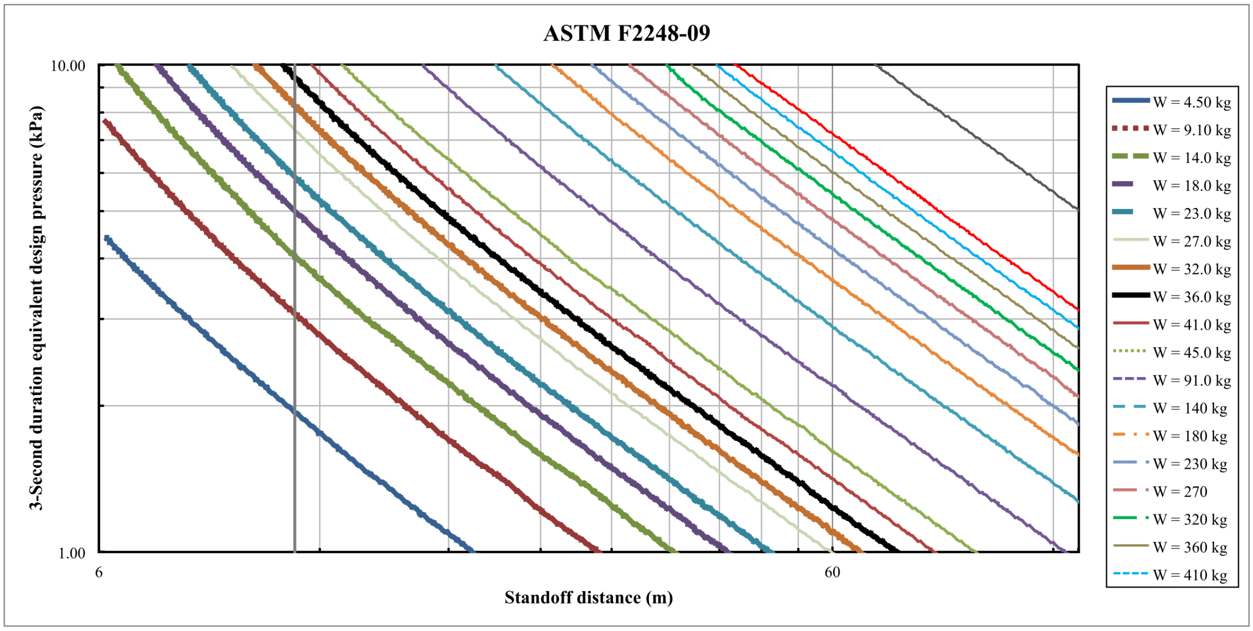

Figure 8: 3 second duration equivalent pressure (q) versus Stand off distance (SD) versus Charge weight (w)

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12 Appendix

This appendix holds the graphs (Fig:demandVSsod and Fig:dimlessloadVSaspect) used for interpolating values needed in the models.

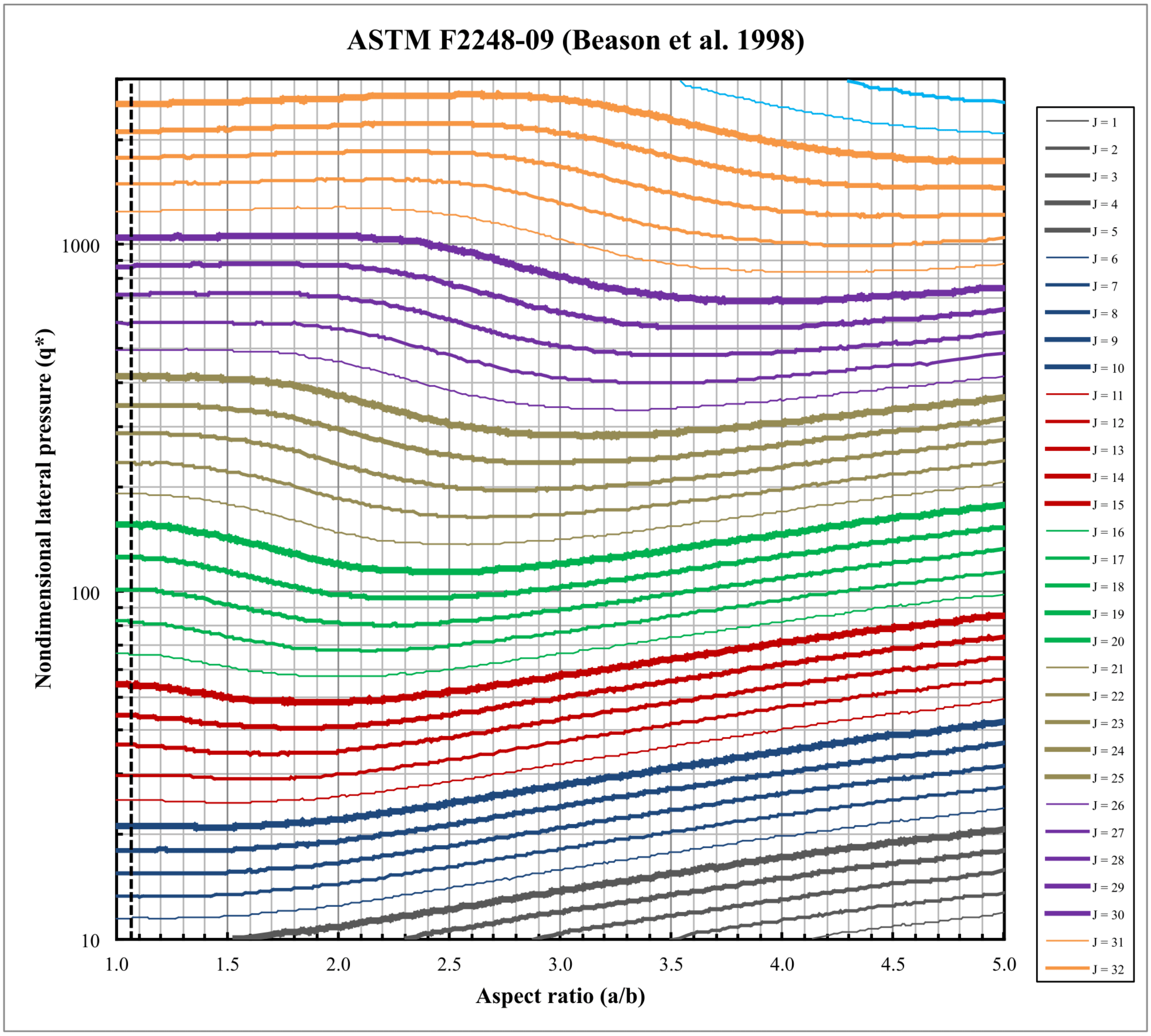

Figure 9: Non dimensional lateral applied load (demand) or pressure ($\hat{q}$) versus Aspect Ratio (AR) versus Stress distribution factor (Function) (J)