Software Requirements Specification for GlassBR

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[According to the standards " tableofcontentshould" be put before all of materials. should not it? —VM]

[No, the table of contents can be listed after the other summary tables. It could also be included earlier, but standardization is more important than other considerations here. —SS] [Yes, you are right, I corrected it in the previous commit. —VM]

[When I made my original comment I didn't realize that the order in the actual case study versions had the table of contents first. The goal is standardization, so let us standardize on the case study versions. Please change back to having the table of contents first. :-) —SS]

1 Revision History

Date	Version	Notes
10/08/18	1.0	initial SRS based on new template
10/20/18	1.1	Minor changes
10/29/18	1.2	Minor fixes based on feedback
10/30/18	1.3	Minor fixes based on Dr.Smith 's feedback
11/11/18	1.4	Major changes based on TM,DD and IM
11/15/18	1.5	Major changes on Tracebility Tables based on TM,DD and IM, Some fixes based on Initial feedback

2 Reference Material

This section records information for easy reference.

2.1 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 lists the symbol, a description and the SI name.

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

2.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The symbols are listed in alphabetical order.

Symbol	Unit	Description
a	m	Plate length (long dimension)
AR	–	Aspect ratio
$\text{AR}_{\max}$	–	Maximum aspect ratio
b	m	Plate width (short dimension)
B	–	Risk function
$d_{\max}$	m	Maximum value for one of the dimensions of the glass plate
$d_{\min}$	m	Minimum value for one of the dimensions of the glass plate
E	Pa	Modulus of elasticity of glass
g	–	Glass type, $g \in \{\text{AN}, \text{HS}, \text{FT}\}$
GTF	–	Glass type factor
h	m	Minimum thickness

is_safeLR	–	Variable that is assigned true when load resistance (capacity) is greater than load (demand)
is_safePb	–	Variable that is assigned true when calculated probability is less than tolerable probability
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 $P_{b_{\text{tol}}}$
k	$\text{N}^{-7}\text{m}^{12}$	Surface flaw parameter
LDF	–	Load duration factor
LR	Pa	Load resistance [Please update to give LR units of Pa —SS]
LSF	–	Load share factor
m	$\text{N}^{-7}\text{m}^{12}$	Surface flaw parameter
NFL	Pa	Non-factored load [Please update to give LR units of Pa —SS]
P_b	–	Probability of breakage
$P_{b_{\text{tol}}}$	–	Tolerable probability of breakage
q	Pa	Applied load (demand)
$\hat{q}$	–	Dimensionless load[According to the change of NFL, LR unit to Pascal, Should'nt the unit of this load be Pascal? —VM] [No, this is a dimensionless load —SS]
$\hat{q}_{\text{tol}}$	–	Tolerable load[According to the change of NFL, LR unit to Pascal, Should'nt the unit of this load be Pascal? —VM] [No, this is a dimensionless load —SS]
SD	m	Stand off distance which is represented in coordinates $(\text{SD}_x, \text{SD}_y, \text{SD}_z)$
$\text{SD}_{\max}$	m	Maximum stand off distance permissible for input
$\text{SD}_{\min}$	m	Minimum stand off distance permissible for input
SD_x	m	Stand off distance (x-component)
SD_y	m	Stand off distance (y-component)
SD_z	m	Stand off distance (z-component)
t	mm	Nominal thickness
		$t \in \{2.5, 2.7, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 12.0, 16.0, 19.0, 22.0\}$
t_d	s	Duration of load
TNT	–	TNT equivalent factor

w	kg	Charge weight
$w_{\max}$	kg	Maximum permissible input charge weight
$w_{\min}$	kg	Minimum permissible input charge weight
w_{TNT}	kg	Explosive mass in equivalent weight of TNT

2.3 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
LG	Laminated Glass
N/A	Not Applicable
PS	Physical System Description
R	Requirement
SD	Stand Off Distance
SRS	Software Requirements Specification
GlassBR	Glass Breakage Analysis Program
T	Theoretical Model
UC	Unlikely Change
TU	Typical Uncertainty

Contents

3 Introduction

Software is helpful to efficiently and correctly predict the blast risk involved with the glass slab. The blast under consideration is any type 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 the document, the scope of the system, the organization of the document, and the characteristics of the intended reader. [I reverted to the origin text. —VM]

3.1 Purpose of Document

This document is used [text removal —SS] as a reference to provide all information necessary to understand and verify GlassBR. The goals and theoretical models used in the GlassBR code are provided, with an emphasis on explicitly identifying assumptions and unambiguous definitions. The SRS is abstract because the contents say *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 [1], the most logical way to present the documentation is still to "fake" a rational design process.

3.2 Scope of Requirements

The scope of the requirements is a single pane of rectangular glass, without any modifications that effect the strength, like etching, drilling, or sandblasting etc. The response type of the glass is assumed to be flexure. [scope re-written to consist of an abstract view of the assumptions. —SS]

3.3 Characteristics of Intended Reader

Reviewers of this documentation should have a strong knowledge of the theory behind glass breakage and blast risk. The reviewers should also have an understanding of second

year calculus, structural mechanics, and computer applications in civil engineering. In addition, reviewers should be familiar with the applicable standards for constructions using glass [2, 3, 4]. The users of GlassBR can have a lower level of expertise, as explained in Section 4.2.

3.4   Organization of Document

The organization of this document follows the template for an SRS for scientific computing software proposed by [5] and [6], with some aspects taken from Volere template 16 [7]. The presentation follows the standard pattern of presenting goals, theories, definitions, and assumptions. For readers who would like a more bottom up approach, they can start reading the data definitions in Section 6.2.4 and trace back to find any additional information they require.

The goal statements (Section 6.1.3) are refined to the theoretical models (Section 6.2.2), and theoretical models to the instance models (Section 6.2.5) . The data definitions (Section 6.2.4) are used to support the definitions of the different models.

4   General System Description

This section provides general information about the system including identifying the interfaces between the system and its environment (system context), describing the user characteristics and listing the system constraints.

4.1   System Context

Figure 1 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.
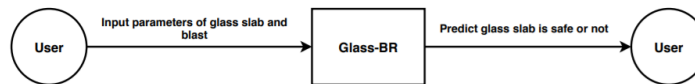

Figure 1: System Context

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 the blast type, ensuring no errors in the data entry.

- Ensure that consistent units are used for input variables.

- Ensure required software assumptions (Section 6.2.1) 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. (Section 6.2.6)

- Predict whether the glass slab is safe to use 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 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   Scope of the Project

[Remove this section; it isn't part of our template. —SS]

   This section presents the scope of the project. It describes the expected use of GlassBR as well as the inputs and outputs of each action. The use cases are input and output, which defines the action of getting the input and displaying the output.

6 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, definitions and finally the instance models.

6.1 Problem Description

A system is needed to efficiently and correctly predict the blast risk involved with the glass. GlassBR is a computer program developed to interpret the inputs to give out the outputs which predict whether the glass slab can withstand the blast under the given conditions.

6.1.1 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 [2].

- *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.

- *Blast resistant glazing* - Glazing that provides protection against air blast pressure generated by explosions.

- *Equivalent TNT charge mass* - Mass of TNT placed on the ground in a hemisphere that represents the design explosive threat.

- *Glass breakage* - The fracture or breakage of any lite or ply in monolithic, laminated, or insulating glass.[would be the scope of the project just monolithic ? —VM] [This definition applies to any of the kinds of glass listed, so the definition shouldn't be changed. However, we will want to add an assumption (separate from this definition) that the software only applies to monolithic glass if that is indeed the case. It has been a long time since I read the original source material. Why do you think the scope is just monolithic? What are the consequences of that assumption? Once you provide me with this information, we can determine whether this is actually an assumption that we should add. —SS][Yes, you are right, the difinition should not be changed. this thaught was more due to the misunderstanding of the difinition of

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AN - HS - FT which has emphasized "flat, monolotic glass",Thus according to the glass type which is a member of AN-HS-FT I thaught scope of the project should be monolotic. I revreted to the origin text. —VM] [Okay. —SS]

- *Glass Type:*

  1. *Annealed (AN)* - A flat, monolithic, glass lite which has uniform thickness where the residual surface stresses are almost zero, as defined in [3].

  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 [4].

  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 (3500 psi) or greater than 52 MPa (7500 psi), as defined in [4].

- *Glass type factor (GTF)* - A multiplying factor for adjusting the LR of different glass types, that is, AN, HS, or FT in monolithic glass, LG (Laminated Glass), or IG (Insulating Glass) constructions. [Glass type is one of the AN, HS or FT types. So, Would the LG and IG be out of the project and these types should be removed from this document. —VM] [Maybe. What is the relationship between GTF and the glass types LG and IG? Can you point me to the right section of the external documentation that I can use to consider your question? —SS][It was more due to the misunderstanding of the difinition of AN - HS - FT which has emphasized "flat, monolotic glass",Thus according to the glass type which is a member of AN-HS-FT I thaught scope of the project should be monolotic. I reverted to the origin text. Besides, I have a new comment: according to the abbrevation table I think the paranthesis for IG and LG should be removed. Should n't it? —VM] [I'm not sure why the parentheses should be removed? It is fairly typical in writing to use the short form, say LG, and then in parentheses expand out the acronym. Maybe I misunderstand your comment? —SS]

- *Lateral* - Perpendicular to the glass surface.

- *Lite* - Pieces of glass that are cut, prepared, and used to create the window or door.

- *Load* - A uniformly distributed lateral pressure.

  1. *Glass weight load* - The dead load component of the glass weight.

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2. *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 [2, (pg. 1, 53)], following A2 and A1 respectively.

3. *Long duration load* - Any load lasting approximately 30 days.

4. *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.

5. *Short duration load* - Any load lasting 3 seconds or less.

6. *Specified design load* - The magnitude in Pa (psf), type (for example, wind or snow) and duration of the load given by the specifying authority.

- *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. [Glass type are one of the AN, HS or FT types. So, Would the LG and IG be out of the project and these types should be removed from this document? —VM] [Same response as above. —SS][You are right. I reverted to the origin text. —VM]

- *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 [3].

- *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.

- *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).

  [Should be "glazing" word removed and would it be replaced with glass surface? —VM] [What does the original source say? These definitions come from the external documentation. We should be consistent with their definitions. We also should add an explicit reference to the source material for these definitions. —SS][You are right, I reverted to the origin text. —VM]

6.1.2 Physical System Description

The physical system of GlassBR, as shown in Figure 2 includes the following elements:

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PS1: The glass slab.

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

Point of
explosion
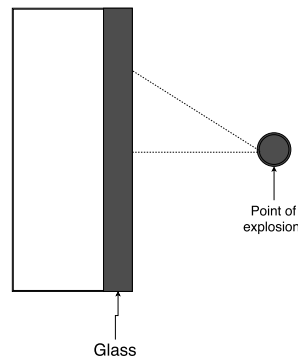
Glass

Figure 2: The physical system

[stand off distance should be shown in the picture. —VM] [I agree. Please add SD to the figure. —SS] [This change to the figure still needs to be made. —SS]

6.1.3 Goal Statements

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

GS1: 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.

6.2 Solution Characteristics Specification

The instance models that govern GlassBR are presented in Section 6.2.5. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

6.2.1 Assumptions

This section simplifies the original problem and helps in developing the theoretical model by filling in the missing information for the physical system. The numbers given in the square brackets refer to the Theoretical Models [Section 6.2.2], General Definitions [Section 6.2.3], Data Definitions [Section 6.2.4], Instance Models [Section 6.2.5], Likely Changes [Section 8], or Unlikely Changes [Section 9], in which the respective assumption is used.

A1: 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.[would be the scope of the project just monolithic ? If yes, It other glasses mush be removed. —VM] [We need to discuss your idea of just making the scope monolithic. I'm not sure why you are making that suggestion. —SS] [It was solved. —VM] [great —SS]

A2: Following [2, (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.

A3: This system only considers the external explosion scenario for its calculations.

A4: The values provided in Section 11.1 are assumed for the duration of load (t_d), and the material properties of m, k, and E. [IM1, DD3, DD5, DD7, DD9]

A5: Glass under consideration is assumed to be a single lite; hence, the value of LSF is equal to 1 for all calculations in GlassBR. [IM2, DD7]

A6: Boundary conditions for the glass slab are assumed to be 4-sided support for all calculations. [IM1]

A7: The response type considered in GlassBR is flexural. [IM1]

A8: With reference to A4, the value of load distribution factor (LDF) is a constant in GlassBR. [DD3]

6.2.2 Theoretical Models

[This project should have these two theoretical models as instanced models and it should introduce two new theoretical models. The new theoretical models should be abstraction of the two chunks currently called theoretical models. The concept of safety is something that should generalize from the GlassBR example. The theoretical model should be reusable in other contexts. The concept of safety would also make sense in the SSP example. There should be two new theoretical models:

1. is_safeProb $= P_{\text{fail}} < P_{\text{tolerable}}$

2. is_safeLoad $=$ capacity $>$ load

For the first equation, the probability of failure is below the tolerable threshold. This can be used in any context where there is some probability of something bad happening. A nuclear reactor has a tiny probability of failure, and this number is less than society's accepted threshold. For the second equation, the capacity and load need to be in the same units, but they don't have to be forces. The capacity for SSP is expressed as shear stress. In another problem it might be tolerable torque. Please add the two new theoretical models and move the existing TMs to be IMs. —SS][Done. Is the TMs 's references right? I changed the labels, If you have better suggestion, Please let me know. —VM]

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

Number	T1
Label	**Safety Probability**
Equation	is_safeProb $= P_{\text{fail}} < P_{\text{tolerable}}$
Description	P_{fail} is the probability of failure. $P_{b_{\text{tol}}}$ is the tolerable threshold entered by the user [all new symbols need to be added to the table of symbols —SS] [Don't mention "entered by the user." This is a theoretical model, not the input output relation for the software. —SS]
Source	[2] [This citation is no longer appropriate here. —SS]
Ref. By	IM1

Number	T2
Label	**Safety Load**
Equation	is_safeLoad = capacity > load
Description	capacity is the Load Resistance (also called capacity).
	load Applied Load or pressure.
Source	[2] [This citation is no longer appropriate here —SS]
Ref. By	IM2

[I think we need descriptive text for the theoretical models. The equations alone cannot speak for themselves. We need to add text that describes the equations, not just a definition of the terms. We should follow the current Drasil approach for doing this. I have posted a question to the Drasil repo to find the terminology that is currently being used. We might add something like a notes field. —SS]

6.2.3 General Definitions

There are no general definitions.

6.2.4 Data Definitions

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given.

Number	DD1
Label	**Risk of Failure (B)**
Equation	$B = \frac{k}{(a \times b)^{m-1}} (Eh^2)^m \times \text{LDF} \times e^J$
Description	B is the risk of failure
	m, k are the surface flaw parameters
	a, b are dimensions of the plate, where $(a > b)$
	E is the modulus of elasticity
	h is the true thickness, which is based on the nominal thickness as shown in DD2
	LDF is the Load Duration Factor, as defined in DD3
	J is the stress distribution factor, as defined in DD4
Source	[2], [8, Eq. 14], [9, Eq. 4-5]
Ref. By	DD12

Number	DD2
Label	**Minimum Thickness (h)**
Equation	$h = h(t)$
Description	h is a function that maps from the nominal thickness (t) to the minimum thickness, as follows: $$h = \frac{1}{1000} \begin{cases} 2.16, & t = 2.5 \\ 2.59, & t = 2.7 \\ 2.92, & t = 3.0 \\ 3.78, & t = 4.0 \\ 4.57, & t = 5.0 \\ 5.56, & t = 6.0 \\ 7.42, & t = 8.0 \\ 9.02, & t = 10.0 \\ 11.91, & t = 12.0 \\ 15.09, & t = 16.0 \\ 18.26, & t = 19.0 \\ 21.44, & t = 22.0 \end{cases}$$
Source	[2]
Ref. By	DD12, DD9, DD7, DD5

Number	DD3
Label	**Load Duration Factor (LDF)**
Equation	$\text{LDF} = \left(\frac{t_d}{60}\right)^{m/16}$
Description	t_d is the duration of the load
	m is a surface flaw parameter
Source	[2]
Ref. By	DD12, DD9

Number	DD4
Label	**Stress Distribution Factor** (J)
Symbols	$J = J(\hat{q}, \mathrm{AR})$
Description	J is the stress distribution factor, which is obtained by interpolating from the data shown in Figure 8
	$\hat{q}$ is the dimensionless load defined in DD7
	AR is the aspect ratio defined in DD11
Source	[2]
Ref. By	DD12

Number	DD5
Label	**Non-Factored Load**
Equations	$\mathrm{NFL} = \frac{\hat{q}_{\mathrm{tol}} E h^4}{(ab)^2}$
Description	E is the modulus of elasticity
	a, b are the dimensions of the plate where $(a > b)$
	h is the true thickness, which is based on the nominal thickness as shown in DD2
	$\hat{q}_{\mathrm{tol}}$ is the tolerable load defined in DD8 [According to the change of NFL unit to Pascal and this equation, Should'nt the unit of this load be Pascal? —VM] [No, the units for E are Pa, so $\hat{q}_{\mathrm{tol}}$ needs to be unitless for NFL to have units of Pa. The hat over the symbol is used to indicate that it is dimensionless. If you look at DD7 the units of q hat are Pa/Pa. —SS]
Source	[2]
Ref. By	DD13

Number	DD6
Label	**Glass Type Factor (GTF)**
Equation	$\text{GTF} = \text{GTF}(g)$
Description	GTF is a function that maps from the glass type (g) to a real number, as follows: $\text{GTF}(g) \equiv (g = \text{AN} \Rightarrow 1.0 \vert g = \text{FT} \Rightarrow 4.0 \vert g = \text{HS} \Rightarrow 2.0)$ AN is annealed glass FT is fully tempered glass HS is heat strengthened glass
Source	[2]
Ref. By	DD7, DD13

Number	DD7
Label	**Dimensionless Load ($\hat{q}$)**
Equation	$\hat{q} = \frac{q(ab)^2}{Eh^4\text{GTF}}$
Description	q is the 3 second equivalent pressure, as given in DD14 a, b are dimensions of the plate, where $(a > b)$ E is the modulus of elasticity h is the true thickness, which is based on the nominal thickness as shown in DD2 GTF is the Glass Type Factor, as given by DD6
Source	[2], [8, Eq. 7]
Ref. By	DD4

Number	DD8
Label	**Tolerable Load ($\hat{q}_{\mathbf{tol}}$)**
Equations	$\hat{q}_{\text{tol}} = \hat{q}_{\text{tol}}(J_{\text{tol}}, \text{AR})$
Description	$\hat{q}_{\text{tol}}$ is the tolerable load which is obtained from Figure 8 using J_{tol} and Aspect Ratio AR (DD11) as parameters using interpolation. Calculation of J_{tol} is defined in DD9.
Source	[2]
Ref. By	DD5

Number	DD9
Label	**Tolerable Stress Distribution Factor ($J_{\mathbf{tol}}$)**
Symbols	$J_{\text{tol}} = \ln[\ln(\frac{1}{1-P_{b_{\text{tol}}}}) \frac{(a \times b)^{m-1}}{k(Eh^2)^m \text{LDF}}]$
Description	J_{tol} is the stress distribution factor calculated with reference to $P_{b_{\text{tol}}}$
	a, b are dimensions of the plate where $(a > b)$
	h is the true thickness, which is based on the nominal thickness as shown in DD2
	m, k are the surface flaw parameters
	LDF is the Load Duration Factor, as defined by DD3
	E is the modulus of elasticity
	$P_{b_{\text{tol}}}$ is the tolerable probability entered by the user
Source	[2]
Ref. By	DD8

Number	DD10
Label	**Stand off Distance (SD)**
Equations	$\mathrm{SD} = \sqrt{\mathrm{SD}_x{}^2 + \mathrm{SD}_y{}^2 + \mathrm{SD}_z{}^2}$
Description	SD is the stand off distance and $(\mathrm{SD}_x, \mathrm{SD}_y, \mathrm{SD}_z)$ are the coordinates for this position
Source	[2]
Ref. By	DD14

Number	DD11
Label	**Aspect Ratio (AR)**
Equations	$\mathrm{AR} = a/b$
Description	AR is the Aspect Ratio and a, b are dimensions of the plate where $(a \geq b)$
Source	[2]
Ref. By	DD4, DD8

Number	DD12
Label	**Probability of Glass Breakage [This should be made a data definition, not an instance model —SS][Done. —VM]**
Equation	$P_b = 1 - e^{-B}$
Description	P_b is the calculated probability of breakage
	B is the risk of failure, as defined in DD1
Source	[2, 9]
Ref. By	IM1

Number	DD13
Label	**Calculation of Capacity (LR)** [This should be made a data definition, not an instance model —SS][Done. —VM]
Equation	LR = NFL × GTF × LSF
Description	LR is the Load Resistance, which is also called capacity
	NFL is the Non-Factored Load, as defined in DD5
	GTF is the Glass Type Factor, as given by DD6
	LSF is the Load Share Factor
Source	[2]
Ref. By	IM2

Number	DD14
Label	**Calculation of Demand (q)** [This should be made a data definition, not an instance model —SS][Done. —VM]
Equation	$q = q(w_{\text{TNT}}, \text{SD})$
Description	q, or demand, is the 3 second equivalent pressure obtained from the Figure 7 by interpolation using stand off distance (SD) and w_{TNT} as parameters
	w_{TNT} is defined as $w_{\text{TNT}} = w \times \text{TNT}$
	w is the charge weight
	TNT is the TNT equivalent factor
	SD is the stand off distance (DD10)
Source	[2]
Ref. By	IM2, DD7

6.2.5 Instance Models

This section transforms the problem defined in Section 6.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 6.2.4 to replace the

abstract symbols in the models identified in Section 6.2.2 and Section 6.2.3.

The goal GS1 are met by the simultaneous solution of IM1, IM2.

Number	IM1
Label	**Safety Req-Pb**
Equation	is_safePb $= P_b < P_{b_{\text{tol}}}$
Description	If is_safePb = True, the glass is considered safe. is_safePb and is_safeLR (from IM2) are either both True or both False.
	P_b is the probability of breakage, as calculated in DD12
	$P_{b_{\text{tol}}}$ is the tolerable probability entered by the user
	[The connection to the theoretical models should be made here. —SS]
Source	[2]
Ref. By	IM2

Number	IM2
Label	**Safety Req-LR**
Equation	is_safeLR = LR $> q$
Description	If is_safeLR = True, the glass is considered to be safe. is_safePb (from IM1) and is_safeLR are either both True or both False.
	LR is the Load Resistance (also called capacity), as defined in DD13 [LR has to have units of Pa, or the comparison to q doesn't make sense — SS] [I have changed in the Table Of Symbols. Is that enough? —VM] [Wherever units are mentioned, they should be mentioned for LR. —SS] [The refinement of the theoretical model also needs to be mentioned for this instance model. —SS]
	q (also referred as the demand) is the 3 second equivalent pressure, as defined in DD14
Source	[2]
Ref. By	IM1

6.2.6 Data Constraints

Table 2 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 column for software constraints restricts the range of inputs to reasonable values. 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.

Section Appendix [11.1] [Update this to point to the Appendix —SS] [Done. —VM] [Remove the word Section. —SS] gives the values of the specification parameters used in Table 2.

Table 2: Input Variables

Var	Physical Constraints	Software Constraints	Typical Value	Uncert.
a	$a > 0$	$d_{\min} \leq a \leq d_{\max}$	1.5 m	10%
AR	$AR \geq 1$	$AR \leq AR_{max}$	1.5	10%
b	$0 < b \leq a$	$d_{\min} \leq b \leq d_{\max}$	1.2 m	10%
$P_{b_{\text{tol}}}$	$0 < P_{b_{\text{tol}}} < 1$	–	0.008	0.1%
SD	$SD > 0$	$SD_{\min} \leq SD \leq SD_{\max}$	45 m	10%
TNT	$TNT > 0$	–	1.0	10%
w	$w > 0$	$w_{\min} \leq w \leq w_{\max}$	42 kg	10%

Note: The values for $d_{\min}$ and $d_{\max}$ are obtained from Figure 3 and the GLASS_BR_0_40b.xslm, which can be found in the Reference directory. The value for $AR_{\max}$ is obtained from Figure 8 and the GLASS_BR_0_40b.xslm. The values for $w_{\min}$, $w_{\max}$, $SD_{\min}$ and $SD_{\max}$ are obtained from Figure 7 and the GLASS_BR_0_40b.xslm.

6.2.7 Properties of a Correct Solution

Table 3 shows the properties that must be exhibited by the calculated output variables.
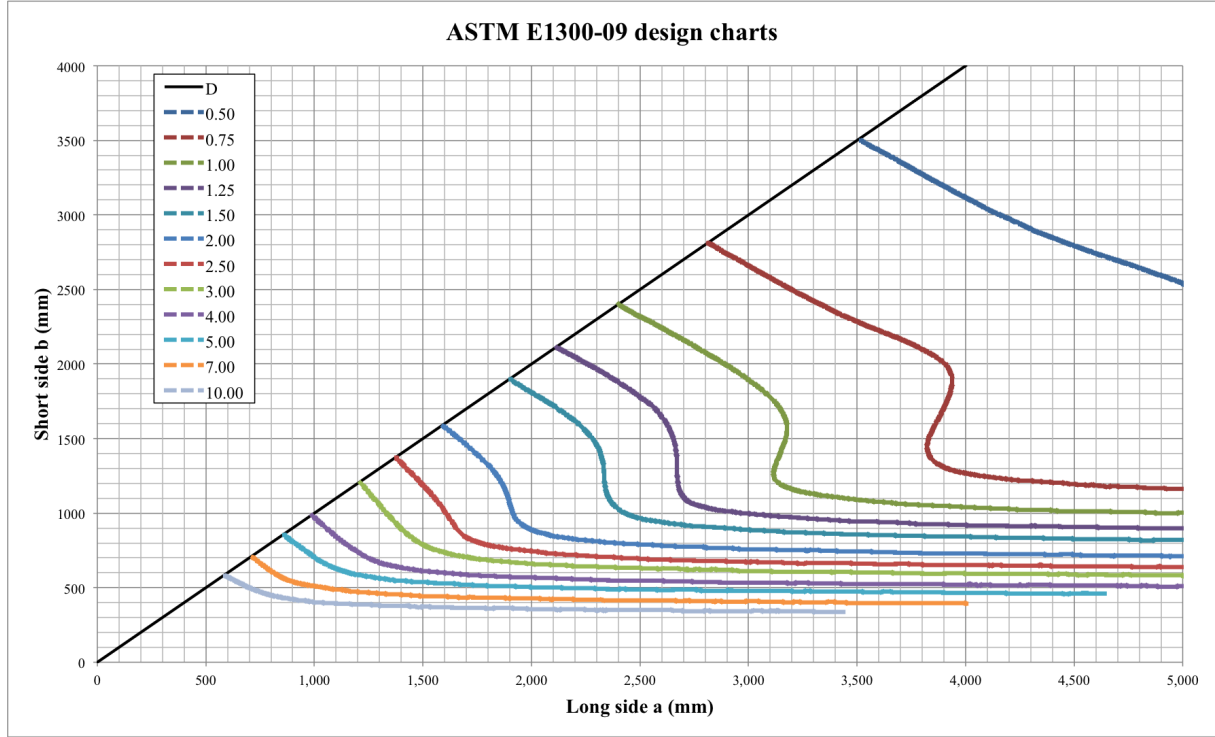
Figure 3: Long side (a) versus Short side (b)

Table 3: Output Variables

Var	Physical Constraints
J	$J_{\min} \leq J \leq J_{\max}$
P_b	$0 < P_b < 1$

7 Requirements

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

7.1   Functional Requirements

R1: User must input the quantities from Table 4, which define the glass dimensions, type of glass, tolerable probability of failure and the characteristics of the blast.

Table 4: R1 Inputs

symbol	unit	description
a	m	Length of the glass slab
b	m	Breadth of the glass slab
g	–	Glass Type, $g \in \{\mathrm{AN, HS, GT}\}$
$P_{b_{\mathrm{tol}}}$	–	Tolerable probability
SD_x	m	Stand off distance (x-component)
SD_y	m	Stand off distance (y-component)
SD_z	m	Stand off distance (z-component)
t	mm	Nominal thickness of the glass slab, $t \in \{2.5, 2.7, 3.0, 4.0, 5.0, 6.0, 8.0, 10.0, 12.0, 16.0, 19.0, 22.0\}$
TNT	–	TNT equivalent factor
w	kg	Charge weight

R2: The system shall set the known values as follows:

- m, k, E, t_d following A4
- LDF from DD3
- LSF following A5
- h from DD2
- GTF from DD6
- SD from DD10
- AR from DD11

[Due to the using same label for R3 and R7 in the initial version, in the tracebility tables, R3 had been missed and it was confusing in the connection between Items with eachother. I corrected their label and in the traceability tables as well. —VM]

R3: The system shall check the entered input values to ensure that they do not exceed the data constraints mentioned in Section 6.2.6. If any of the input parameters are out of bounds, an error message is displayed and the calculations stop.

R4: Output the input quantities from R1 and the known quantities from R2.

R5: If is_safePb $\wedge$ is_safeLR (from IM1 and IM2) are true, 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."

R6: Output the following quantities:

- Probability of breakage (P_b) (DD12)
- Risk of failure (B) (DD1)
- Load resistance (LR) (DD13)
- Applied load (demand) (q) (DD14)
- Stress distribution factor (J) (DD4)
- Non-factored load (NFL) (DD5)
- Glass type factor (GTF) (DD6)
- Dimensionless load ($\hat{q}$) (DD7)
- Tolerable load ($\hat{q}_{\text{tol}}$) (DD8)
- Stress distribution factor based on P_b (J_{tol}) (DD9)
- Minimum thickness (h) (DD2)
- Aspect Ratio (AR) (DD11)

R7: The system shall check the calculated output values to ensure that they do not exceed the data constraints mentioned in Section 6.2.6. If any of the output values are out of bounds, an error message is displayed and the calculations stop.

7.2 Non-Functional Requirements

GlassBR is intended to be an educational tool, therefore accuracy and performance speed are secondary program priorities. Instead, the following non-functional requirements are prioritized:

[To update your nonfunctional requirements, I suggest that you have a look at what Olu is doing in the Game Physics SRS. To make the requirements unambiguous, you can reference your System VnV Plan. —SS]

NFR1: Correctness, achieved if the outputs of the code have the properties described in 6.2.7. [No, this is not correct. Correctness depends on meeting the requirements. This doesn't make sense as a separate NFR. What you are likely intending to refer to is accuracy. Accuracy is a difficult requirement to state in a measurable way. I think what you could say here is that accuracy is important, but it cannot reasonably be specified *a priori*. What we will do instead is measure the accuracy *a posterior* by comparing the output to an existing implementation for GlassBR. —SS]

NFR2: Portability, achieved if GlassBR is installed on two operating system MAC and Windows with processors and instruction sets. [Installing it doesn't make it portable. What you want is to measure the difference in the calculated values and ensure that they are within an acceptable tolerance. —SS]

NFR3: Reusability, achieved if the code is modularized. [Not necessarily —SS]

NFR4: Maintainability, achieved if the traceability between requirements, assumptions, theoretical models, general definitions, data definitions, instance models, likely changes, and modules is completely recorded in traceability matrices in the SRS and module guide. [Again, this may help with maintainability, but it doesn't ensure it is achieved. —SS]

8 Likely Changes

LC1: A3 - The system currently only calculates for external blast risk. In the future, calculations can be added for the internal blast risk.

LC2: A4, A8 - 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.

LC3: A5 - The software may be changed to accommodate more than a single lite.

LC4: A6 - The software may be changed to accommodate more boundary conditions than 4-sided support.

LC5: A7 - The software may be changed to consider more than just flexure of the glass.

9 Unlikely Changes

UC1: The goal of the system is to predict whether the glass slab under consideration can withstand an explosion of a certain degree.

UC2: A2 requires that the glass is not altered in any way. Therefore, this cannot be used on altered glass.

10 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. Table 5 shows the dependencies of theoretical models, instance models, and data definitions with each other. Table 6 shows the dependencies of requirements on theoretical models, instance models, data definitions and data constraints. Table 7 shows the dependencies of theoretical models, instance models, data definitions, likely changes and requirements on the assumptions. [Some DDs had been missed in the initial version, I added prior and new DDs and new changes. —VM]

	T1	T2	IM1	IM2	DD1	DD2	DD3	DD4	DD5	DD6	DD7	DD8	DD9	DD10	DD11	DD12	DD13	DD14
T1																		
T2																		
IM1	X			X												X		
IM2		X	X														X	X
DD1																		
DD2																		
DD3																		
DD4											X				X			
DD5						X						X						
DD6																		
DD7						X				X								X
DD8													X		X			
DD9						X	X											
DD10																		
DD11																		
DD12					X	X	X	X										
DD13									X	X								
DD14														X				

Table 5: Traceability Matrix Showing the Connections Between Items of Different Sections

[The theoretical models shouldn't trace to the requirements at all. The requirements should trace to the instance models. The instance models should trace to the theoretical models. —SS]

	T1	T2	IM1	IM2	DD1	DD2	DD3	DD4	DD5	DD6	DD7	DD8	DD9	DD10	DD11	DD12	DD13	DD14	6.2.6	R1	R2
R1																					
R2						X	X			X				X	X						
R3																			X		
R4																				X	X
R5	X	X	X	X																	
R6					X	X		X	X	X	X	X	X		X	X	X	X			
R7																			X		

Table 6: Traceability Matrix Showing the Connections Between Requirements and Other Items.

	A1	A2	A3	A4	A5	A6	A7	A8
T1								
T2								
IM1				X		X	X	
IM2					X			
IM??								
DD1								
DD2								
DD3				X				X
DD4								
DD5				X				
DD6								
DD7					X			
DD8								
DD9				X				
LC1			X					
LC2				X				X
LC3					X			
LC4						X		
LC5							X	
R1								
R2				X	X			X
R??								
R4								
R5								
R6								

Table 7: Traceability Matrix Showing the Connections Between Assumptions and Other Items

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. Figure 4 shows the dependencies of theoretical models, instance models, and data definitions on each other. Figure 5 shows the dependencies of requirements on theoretical models, instance models, data definitions and data constraints. Figure 6 shows the dependencies of theoretical models, instance models, data definitions, requirements and likely changes on assumptions.

NOTE: Building a tool to automatically generate the graphical representation of the matrix by scanning the labels and reference can be future work.
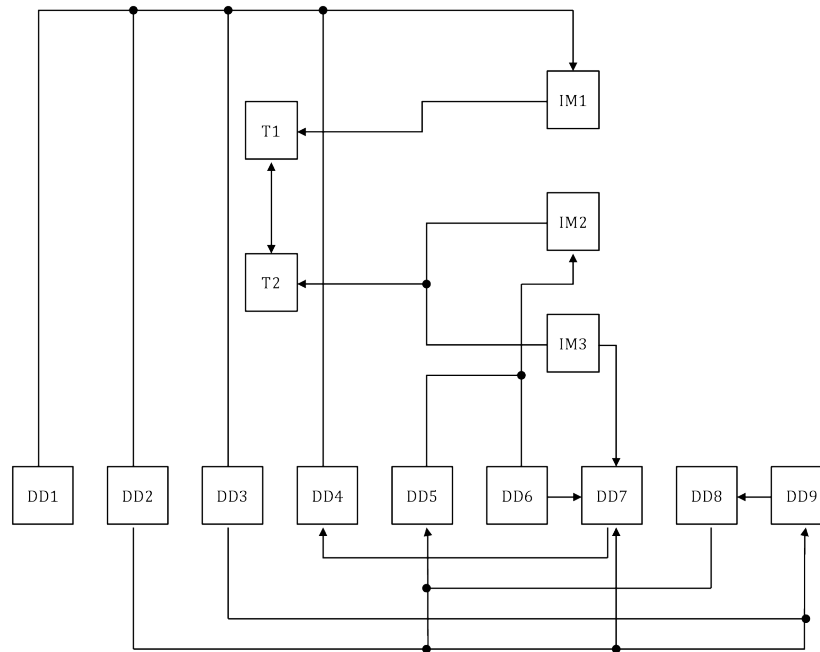

Figure 4: Traceability Graph Showing the Connections Between Items of Different Sections.
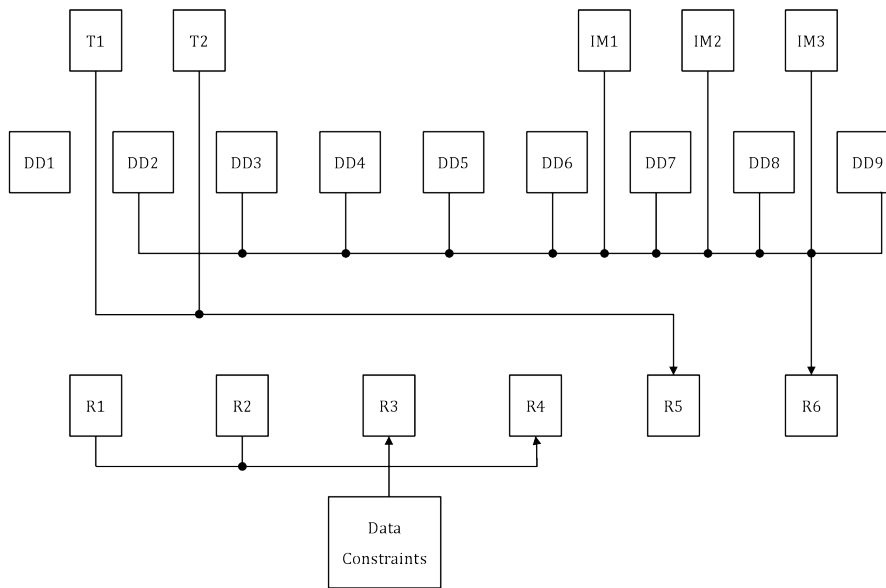
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Figure 5: Traceability Graph Showing the Connections Between Requirements and Other Items.
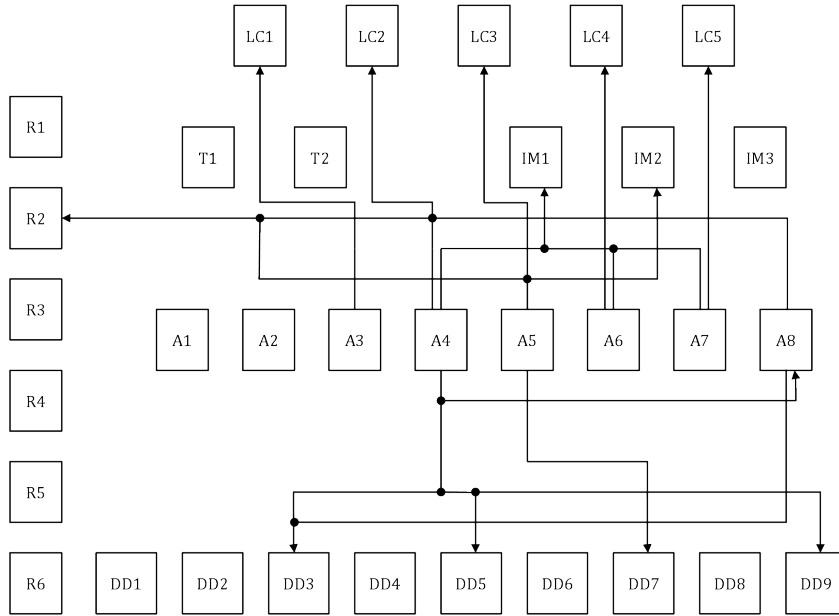
Figure 6: Traceability Graph Showing the Connections Between Assumptions and Other Items.

11   Appendix

This appendix holds the graphs (Figure 7 and Figure 8) used for interpolating values needed in the models.

11.1   Symbolic Parameters

[This section is not on the template,Should it be removed? —VM]

   [No, do not remove the section. It is in the template, but under a different name. You can move this section to an Appendix under the heading "Symbolic Parameters." —SS]
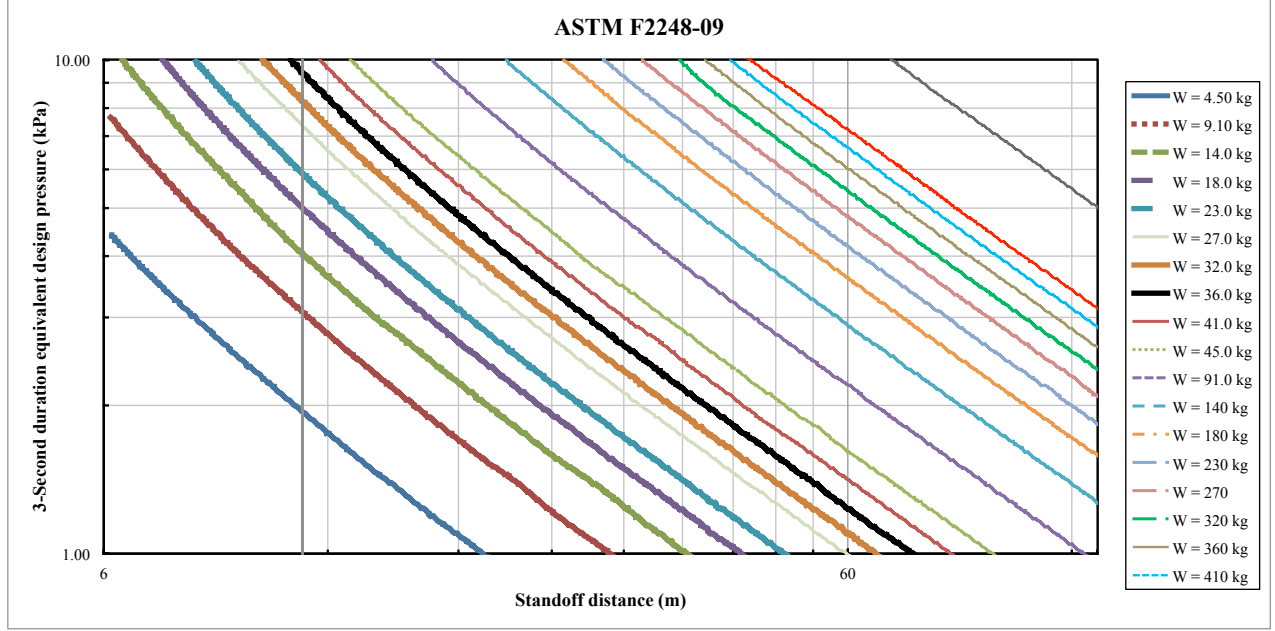
Figure 7: 3 second equivalent pressure (q) versus Stand off distance (SD) versus Charge weight (w)

[Done. —VM]

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

Symbol	Description	Value	Unit
AR_{max}	maximum aspect ratio	5.0	–
d_{max}	maximum value for one of the dimensions of the glass plate	5.0	m
d_{min}	minimum value for one of the dimensions of the glass plate	0.1	m
E	modulus of elasticity of glass	7.17×10^{10}	Pa
k	surface flaw parameter	2.86×10^{-53}	$\frac{\text{m}^{12}}{\text{N}^7}$
$J_{\max}$	maximum value for the stress distribution factor	32.0	–
$J_{\min}$	minimum value for the stress distribution factor	1.0	–
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	130.0	m

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SD_{min}	minimum stand off distance permissible for input	6.0	m
t_d	duration of load	3	s
w_{max}	maximum permissible input charge weight	910.0	kg
w_{min}	minimum permissible input charge weight	4.5	kg

Table 8: Auxiliary Constants

12 References

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[3] ASTM, "Standard specification for flat glass," 2016.

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[7] S. Robertson and J. Robertson, *Mastering the Requirements Process*, ch. Volere Requirements Specification Template, pp. 353–391. New York, NY, USA: ACM Press/Addison-Wesley Publishing Co, 1999.

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[9] W. L. Beason, T. L. Kohutek, and J. M. Bracci, "Basis for ASTME E 1300 annealed glass thickness selection charts," *Journal of Structural Engineering*, vol. 124, pp. 215–221, February 1998.
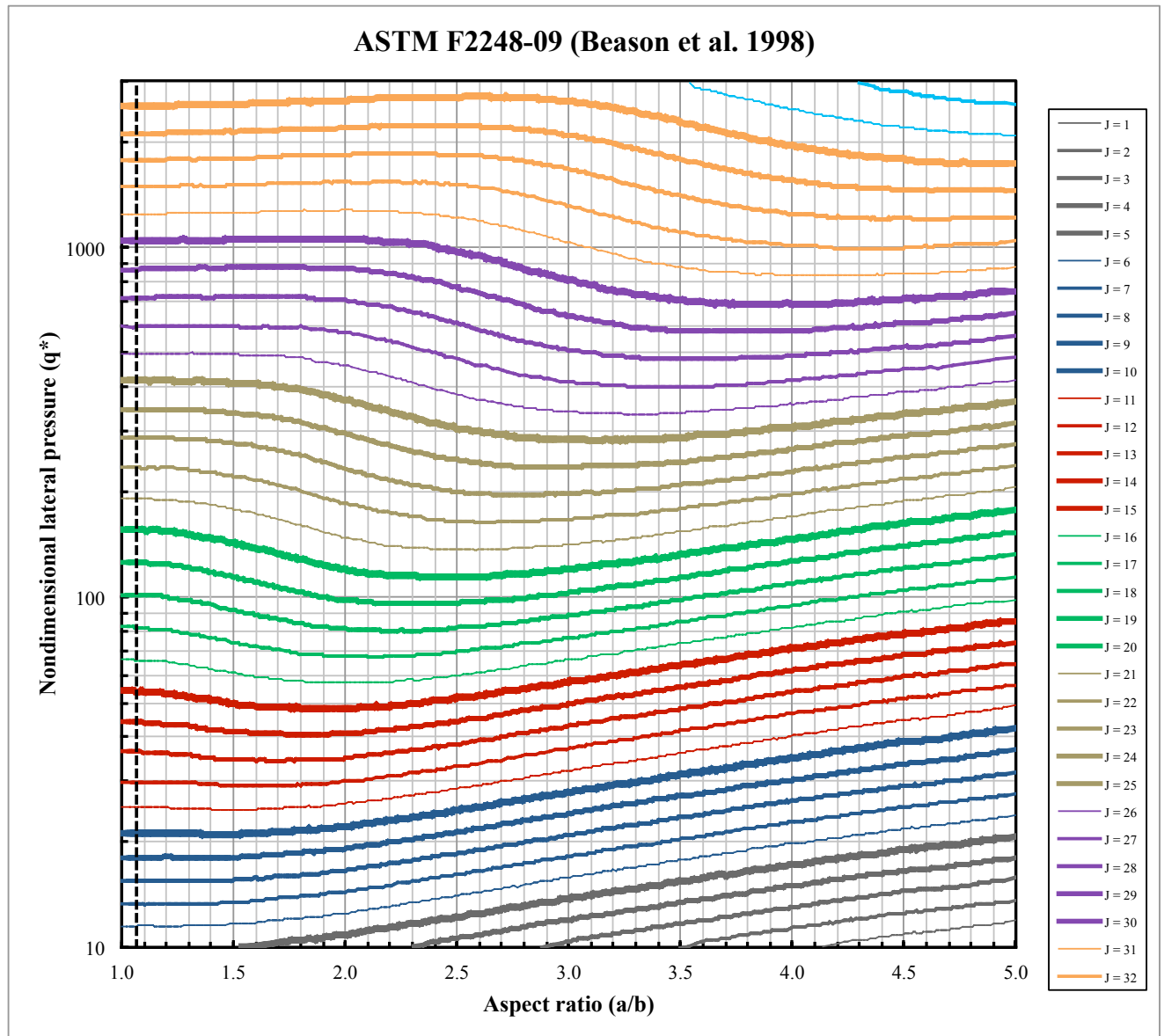
Figure 8: Non dimensional lateral load ($\hat{q}$) versus Aspect Ratio (AR) versus Stress distribution factor (Function) (J)