# Software Requirements Specification for GlassBR

Vajiheh Motamer and W. Spencer Smith

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

# 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 |

# 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 |
| $\mathrm{AR}_{\mathrm{max}}$ | – | Maximum aspect ratio |
| $b$ | m | Plate width (short dimension) |
| $B$ | – | Risk function |
| $d_{\mathrm{max}}$ | m | Maximum value for one of the dimensions of the glass plate |
| $d_{\mathrm{min}}$ | m | Minimum value for one of the dimensions of the glass plate |
| $E$ | Pa | Modulus of elasticity of glass |
| $g$ | – | Glass type, $g \in \{\mathrm{AN}, \mathrm{HS}, \mathrm{FT}\}$ |
| 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) |
| $J_{\mathrm{max}}$ | – | Maximum value for the stress distribution factor |
| $J_{\mathrm{min}}$ | – | Minimum value for the stress distribution factor |

| | | |
|---|---|---|
| $J_{\text{tol}}$ | – | 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 | – | Load resistance |
| LSF | – | Load share factor |
| $m$ | $\text{N}^{-7}\text{m}^{12}$ | Surface flaw parameter |
| NFL | – | Non-factored load |
| $P_b$ | – | Probability of breakage |
| $P_{b_{\text{tol}}}$ | – | Tolerable probability of breakage |
| $q$ | Pa | Applied load (demand) |
| $\hat{q}$ | – | Dimensionless load |
| $\hat{q}_{\text{tol}}$ | – | Tolerable load |
| SD | m | Stand off distance which is represented in coordinates $(\text{SD}_x, \text{SD}_y, \text{SD}_z)$ |
| $\text{SD}_{\text{max}}$ | m | Maximum stand off distance permissible for input |
| $\text{SD}_{\text{min}}$ | m | Minimum stand off distance permissible for input |
| $\text{SD}_{\text{x}}$ | m | Stand off distance (x-component) |
| $\text{SD}_{\text{y}}$ | m | Stand off distance (y-component) |
| $\text{SD}_{\text{z}}$ | 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 |
| $w_{\text{max}}$ | kg | Maximum permissible input charge weight |
| $w_{\text{min}}$ | kg | Minimum permissible input charge weight |
| $w_{\text{TNT}}$ | 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 a type of man-made blast load. 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.

## 3.1 Purpose of Document

This document is intended to be used as a reference to provide all information necessary to understand and verify the analysis 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 includes getting all input parameters related to the glass slab and also the parameters related to blast type. GlassBR predicts whether a glass slab under the given conditions is safe or not.

## 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 5.2.4 and trace back to find any additional information they require.

The goal statements (Section 5.1.3) are refined to the theoretical models (Section 5.2.2), and theoretical models to the instance models (Section 5.2.5) . The data definitions (Section 5.2.4) 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.

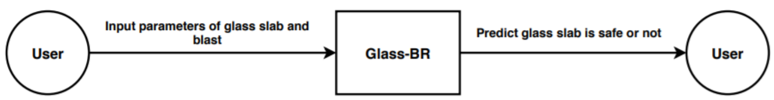


Figure 1: System Context

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 5.2.1) 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 data constraints (Section 5.2.6)
  - Predict whether the glass slab is safe to use or not.

## 4.2 User Characteristics

The end user of GlassBR should have an understanding of undergraduate Level 1 Calculus and Physics and to have an understanding of theory behind Shattering Science and Glass Physics.

## 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, definitions and finally the instance models.

## 5.1 Problem Description

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. The blast under consideration is a type of man-made blast load. Software is helpful to efficiently and correctly predict the blast risk involved with the glass slab using an intuitive interface.

### 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:

- *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]

- *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 the monolithic glass. [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]

- *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.
  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), blast load type 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. [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]

- *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 glass surface to the center 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]

### 5.1.2 Physical System Description

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

PS1: The glass slab.

PS2: The point of explosion. Where the bomb, or a man-made explosive, is located.

PS3: The stand off distance is the distance between the point of explosion and the glass.

[ stand off distance should be shown in the picture. —VM]

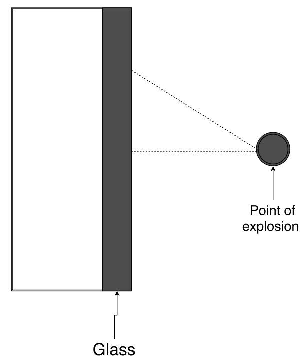


Figure 2: The physical system

#### 5.1.3 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.

### 5.2 Solution Characteristics Specification

The instance models that govern GlassBR are presented in Subsection 5.2.5. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

#### 5.2.1 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 model [T], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], 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]

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 10 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]

### 5.2.2 Theoretical Models

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

| Number | T1 |
|---|---|
| Label | **Safety Req-Pb** |
| Equation | $\text{is\_safePb} = P_b < P_{b_{\text{tol}}}$ |
| Description | If is_safePb = True, the glass is considered safe. is_safePb and is_safeLR (from T2) are either both True or both False.<br><br>$P_b$ is the probability of breakage, as calculated in IM1<br><br>$P_{b_{\text{tol}}}$ is the tolerable probability entered by the user |
| Source | [2] |
| Ref. By | T2 |

| Number | T2 |
|---|---|
| Label | **Safety Req-LR** |
| Equation | is_safeLR = LR $> q$ |
| Description | If is_safeLR = True, the glass is considered to be safe. is_safePb (from T1) and is_safeLR are either both True or both False.<br>LR is the Load Resistance (also called capacity), as defined in IM2<br>$q$ (also referred as the demand) is the 3 second equivalent pressure, as defined in IM3 |
| Source | [2] |
| Ref. By | T1 |

### 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. 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<br>$m, k$ are the surface flaw parameters<br>$a$, $b$ are dimensions of the plate, where $(a > b)$<br>$E$ is the modulus of elasticity<br>$h$ is the true thickness, which is based on the nominal thickness as shown in DD2<br>LDF is the Load Duration Factor, as defined in DD3<br>$J$ is the stress distribution factor, as defined in DD4 |
| Source | [2], [8, Eq. 14], [9, Eq. 4-5] |
| Ref. By | IM1 |

| | |
|---|---|
| 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 | IM1, DD9, DD7, DD5 |

| | |
|---|---|
| Number | DD3 |
| Label | **Load Duration Factor (LDF)** |
| Equation | $\text{LDF} = (\frac{t_d}{60})^{m/16}$ |
| Description | $t_d$ is the duration of the load<br>$m$ is a surface flaw parameter |
| Source | [2] |
| Ref. By | IM1, 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<br>$\hat{q}$ is the dimensionless load defined in DD7<br>AR is the aspect ratio defined in DD11 |
| Source | [2] |
| Ref. By | IM1 |

| 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<br>$a$, $b$ are the dimensions of the plate where $(a > b)$<br>$h$ is the true thickness, which is based on the nominal thickness as shown in DD2<br>$\hat{q}_{\mathrm{tol}}$ is the tolerable load defined in DD8 |
| Source | [2] |
| Ref. By | IM2 |

| Number | DD6 |
|---|---|
| Label | **Glass Type Factor (GTF)** |
| Equation | $\mathrm{GTF} = \mathrm{GTF}(g)$ |
| Description | GTF is a function that maps from the glass type $(g)$ to a real number, as follows:<br>$\mathrm{GTF}(g) \equiv (g = \mathrm{AN} \Rightarrow 1.0 \vert g = \mathrm{FT} \Rightarrow 4.0 \vert g = \mathrm{HS} \Rightarrow 2.0)$<br>AN is annealed glass<br>FT is fully tempered glass<br>HS is heat strengthened glass |
| Source | [2] |
| Ref. By | DD7, IM2 |

| Number | DD7 |
|---|---|
| Label | **Dimensionless Load** ($\hat{q}$) |
| Equation | $\hat{q} = \frac{q(ab)^2}{Eh^4 \mathrm{GTF}}$ |
| Description | $q$ is the 3 second equivalent pressure, as given in IM3<br>$a$, $b$ are dimensions of the plate, where ($a > b$)<br>$E$ is the modulus of elasticity<br>$h$ is the true thickness, which is based on the nominal thickness as shown in DD2<br>GTF is the Glass Type Factor, as given by DD6 |
| Source | [2], [8, Eq. 7] |
| Ref. By | DD4 |

| Number | DD8 |
|---|---|
| Label | **Tolerable Load** ($\hat{q}_{\mathrm{tol}}$) |
| Equations | $\hat{q}_{\mathrm{tol}} = \hat{q}_{\mathrm{tol}}(J_{\mathrm{tol}}, \mathrm{AR})$ |
| Description | $\hat{q}_{\mathrm{tol}}$ is the tolerable load which is obtained from Figure 8 using $J_{\mathrm{tol}}$ and Aspect Ratio AR (DD11) as parameters using interpolation. Calculation of $J_{\mathrm{tol}}$ 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 | $J_{\text{tol}}$ is the stress distribution factor calculated with reference to $P_{b_{\text{tol}}}$<br><br>$a$, $b$ are dimensions of the plate where ($a > b$)<br><br>$h$ is the true thickness, which is based on the nominal thickness as shown in DD2<br><br>$m$, $k$ are the surface flaw parameters<br><br>LDF is the Load Duration Factor, as defined by DD3<br><br>$E$ is the modulus of elasticity<br><br>$P_{b_{\text{tol}}}$ is the tolerable probability entered by the user |
| Source | [2] |
| Ref. By | DD8 |

| | |
|---|---|
| Number | DD10 |
| Label | **Stand off Distance (SD)** |
| Equations | $\text{SD} = \sqrt{\text{SD}_x{}^2 + \text{SD}_y{}^2 + \text{SD}_z{}^2}$ |
| Description | SD is the stand off distance and $(\text{SD}_x, \text{SD}_y, \text{SD}_z)$ are the coordinates for this position |
| Source | [2] |
| Ref. By | IM3 |

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

### 5.2.5 Instance Models

This section transforms the problem defined in Section 5.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 5.2.4 to replace the abstract symbols in the models identified in Section 5.2.2 and Section 5.2.3.

The goal GS1 are met by the simultaneous solution of IM1, IM2 and IM3.

| | |
|---|---|
| Number | IM1 |
| Label | **Probability of Glass Breakage** |
| Equation | $P_b = 1 - e^{-B}$ |
| Description | $P_b$ is the calculated probability of breakage<br>$B$ is the risk of failure, as defined in DD1 |
| Source | [2, 9] |
| Ref. By | T1 |

| | |
|---|---|
| Number | IM2 |
| Label | **Calculation of Capacity (LR)** |
| Equation | $\text{LR} = \text{NFL} \times \text{GTF} \times \text{LSF}$ |
| Description | LR is the Load Resistance, which is also called capacity<br>NFL is the Non-Factored Load, as defined in DD5<br>GTF is the Glass Type Factor, as given by DD6<br>LSF is the Load Share Factor |
| Source | [2] |
| Ref. By | T2 |

| Number | IM3 |
|---|---|
| Label | **Calculation of Demand** ($q$) |
| 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 $w_{\text{TNT}}$ as parameters<br>$w_{\text{TNT}}$ is defined as $w_{\text{TNT}} = w \times \text{TNT}$<br>$w$ is the charge weight<br>TNT is the TNT equivalent factor<br>SD is the stand off distance (DD10) |
| Source | [2] |
| Ref. By | T2, DD7 |

#### 5.2.6 Data Constraints

Table 2 and Table 3 show the data constraints on the input and output variables, respectively. 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.

Section 10 gives the values of the specification parameters used in Table 2.

Table 2: Input Variables

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

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

Figure 7 and the GLASS_BR_0_40b.xslm.

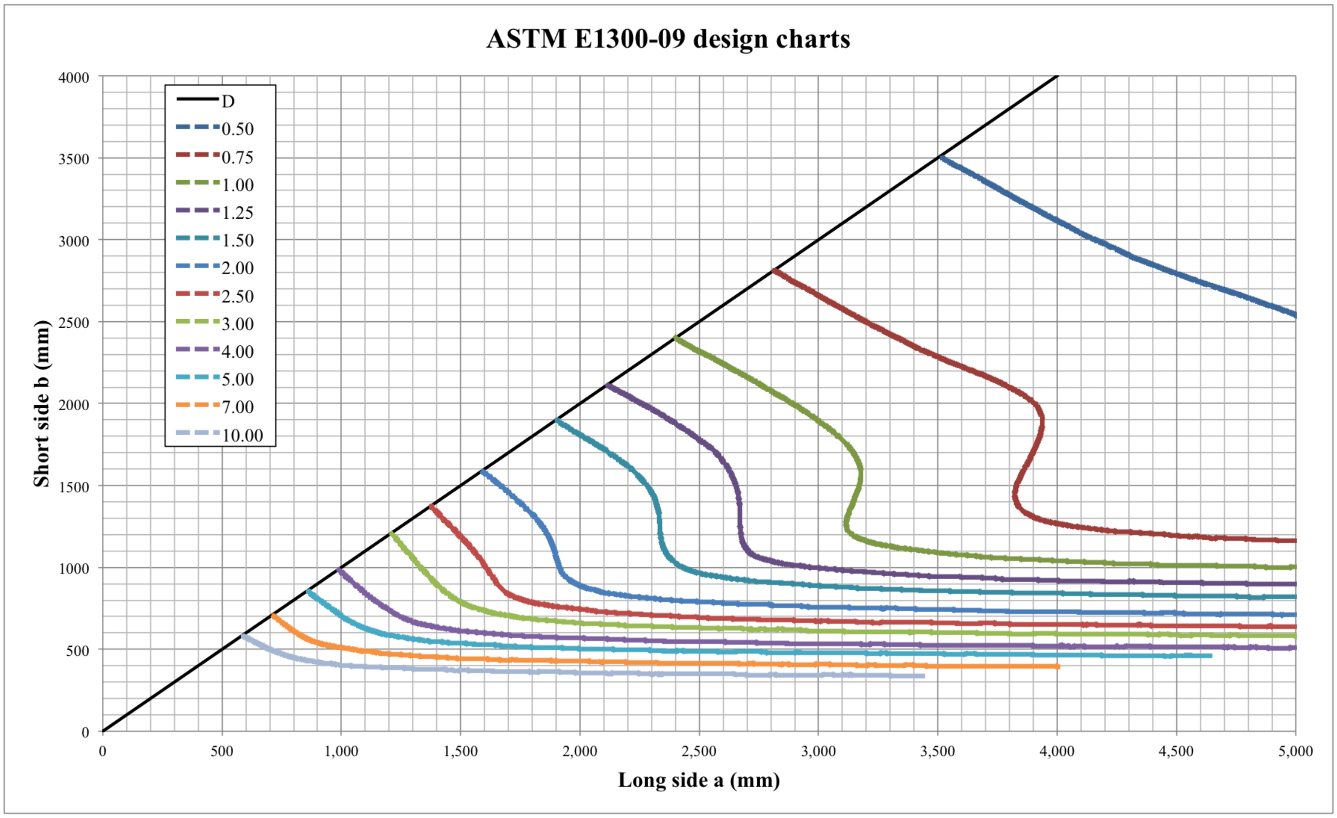


Figure 3: Long side (a) versus Short side (b)

Table 3: Output Variables

| Var | Physical Constraints |
|---|---|
| $J$ | $J_{\min} \le J \le J_{\max}$ |
| $P_b$ | $0 < P_b < 1$ |

### 5.2.7 Properties of a Correct Solution

A correct solution must exhibit conformation to the system of non-linear equations presented in IM1, a system of linear equations presented in IM2, and a concave up function for calculation of IM3.

# 6 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.

## 6.1 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, $g \in \{\mathrm{AN}, \mathrm{HS}, \mathrm{GT}\}$ |
| $P_{b_{\mathrm{tol}}}$ | – | Tolerable probability |
| $\mathrm{SD}_x$ | m | Stand off distance ($x$-component) |
| $\mathrm{SD}_y$ | m | Stand off distance ($y$-component) |
| $\mathrm{SD}_z$ | 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

R3: The system shall check the entered input values to ensure that they do not exceed the data constraints mentioned in Section 5.2.6. 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 T1 and T2) 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 ($P_b$) (IM1)
- Risk of failure ($B$) (DD1)
- Load resistance (LR) (IM2)
- Applied load (demand) ($q$) (IM3)
- 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 $P_b$ ($J_{\text{tol}}$) (DD9)
- Minimum thickness ($h$) (DD2)
- Aspect Ratio (AR) (DD11)

### 6.2 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:

NFR1: Correctness, achieved if the outputs of the code have the properties described in 5.2.7.

NFR2: Portability, achieved if GlassBR is installed on two operating system MAC and Windows with processors and instruction sets.

NFR3: Reusability, achieved if the code is modularized.

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.

## 7 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.

# 8 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.

# 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. 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.

| | T1 | T2 | IM1 | IM2 | IM3 | DD1 | DD2 | DD3 | DD4 | DD5 | DD6 | DD7 | DD8 | DD9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1 | | X | X | | | | | | | | | | | |
| T2 | X | | | X | X | | | | | | | | | |
| IM1 | | | | | | X | X | X | X | | | | | |
| IM2 | | | | | | | | | | X | X | | | |
| IM3 | | | | | | | | | | | | | | |
| DD1 | | | | | | | | | | | | | | |
| DD2 | | | | | | | | | | | | | | |
| DD3 | | | | | | | | | | | | | | |
| DD4 | | | | | | | | | | | | X | | |
| DD5 | | | | | | | X | | | | | | X | |
| DD6 | | | | | | | | | | | | | | |
| DD7 | | | | | X | | X | | | | X | | | |
| DD8 | | | | | | | | | | | | | | X |
| DD9 | | | | | | | X | X | | | | | | |

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

| | T1 | T2 | IM1 | IM2 | IM3 | DD1 | DD2 | DD3 | DD4 | DD5 | DD6 | DD7 | DD8 | DD9 | 5.2.6 | R1 | R2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R1 | | | | | | | | | | | | | | | | | |
| R2 | | | | | | | | | | | | | | | | | |
| R3 | | | | | | | | | | | | | | | X | | |
| R4 | | | | | | | | | | | | | | | | X | X |
| R5 | X | X | | | | | | | | | | | | | | | |
| R6 | | | X | X | X | | X | X | X | X | X | X | X | 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 | | | |
| IM3 | | | | | | | | |
| 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 |
| R3 | | | | | | | | |
| 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.

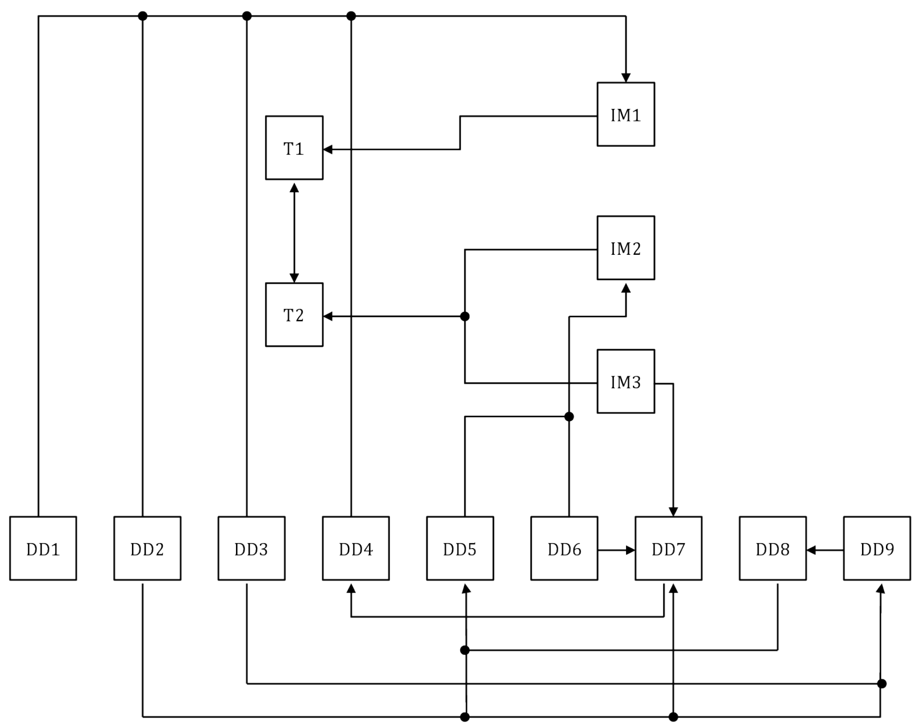


Figure 4: Traceability Graph Showing the Connections Between Items of Different Sections.

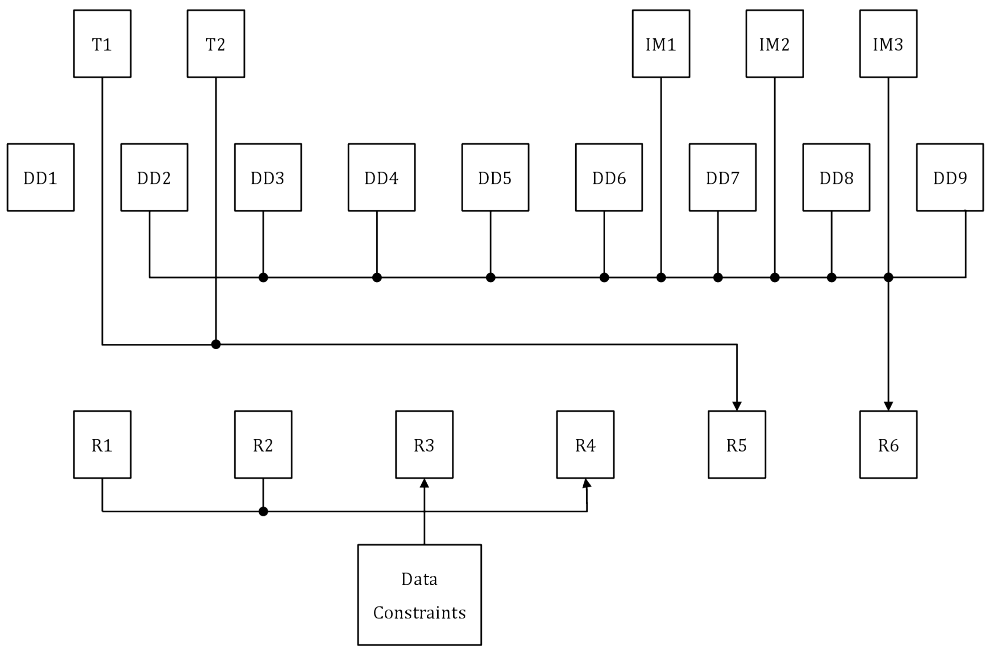


Figure 5: Traceability Graph Showing the Connections Between Requirements and Other Items.

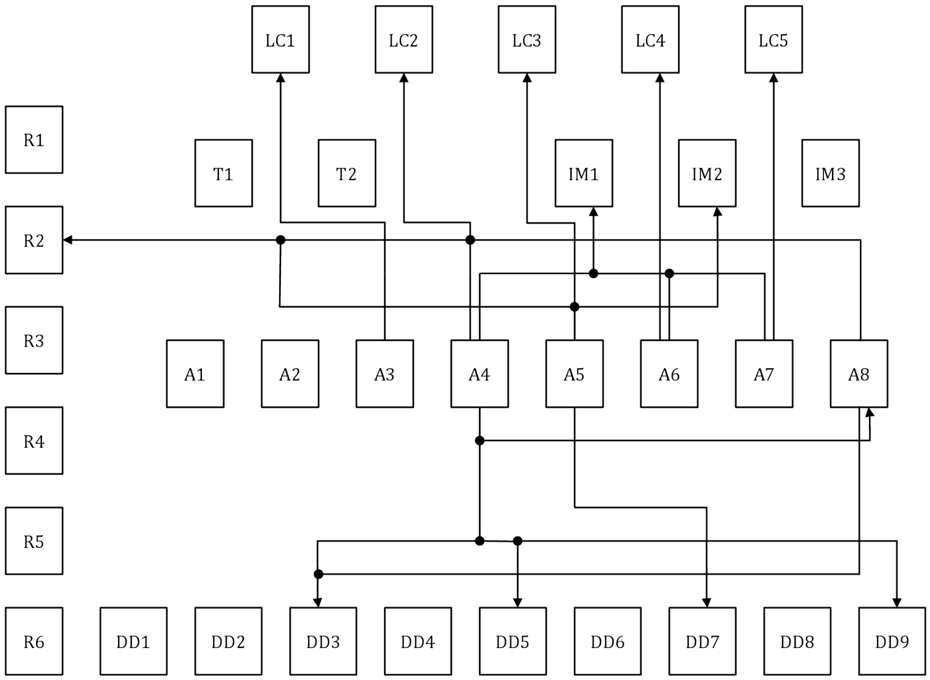


Figure 6: Traceability Graph Showing the Connections Between Assumptions and Other Items.

# 10 Values of Auxiliary Constants

[This section is not on the template,Should it be removed? —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 | $7.17 \times 10^{10}$ | Pa |
| $k$ | surface flaw parameter | $2.86 \times 10^{-53}$ | $\frac{m^{12}}{N^7}$ |
| $J_{\text{max}}$ | maximum value for the stress distribution factor | 32.0 | – |
| $J_{\text{min}}$ | minimum value for the stress distribution factor | 1.0 | – |
| LSF | load share factor | 1 | – |

| | | | |
|---|---|---|---|
| $m$ | surface flaw parameter | 7 | $\frac{\text{m}^{12}}{\text{N}^7}$ |
| $\text{SD}_{max}$ | maximum stand off distance permissible for input | 130.0 | m |
| $\text{SD}_{min}$ | 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

# 11 References


[1] D. L. Parnas and P. Clements, "A rational design process: How and why to fake it," *IEEE Transactions on Software Engineering*, vol. 12, no. 2, pp. 251–257, February 1986.

[2] ASTM, "Standard practice for determining load resistance of glass in buildings," 2009.

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

[4] ASTM, "Standard specification for heat-strengthened and fully tempered flat glass," 2012.

[5] N. Koothoor, "A document drive approach to certifying scientific computing software," Master's thesis, McMaster University, Hamilton, Ontario, Canada, 2013.

[6] W. S. Smith and L. Lai, "A new requirements template for scientific computing," in *Proceedings of the First International Workshop on Situational Requirements Engineering Processes – Methods, Techniques and Tools to Support Situation-Specific Requirements Engineering Processes, SREP'05* (J. Ralyté, P. Ȧgerfalk, and N. Kraiem, eds.), (Paris, France), pp. 107–121, In conjunction with 13th IEEE International Requirements Engineering Conference, 2005.

[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.

[8] M. Campidelli, "Glass-BR software for the design and risk assessment of glass facades subjected to blast loading."

[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.


# 12 Appendix

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

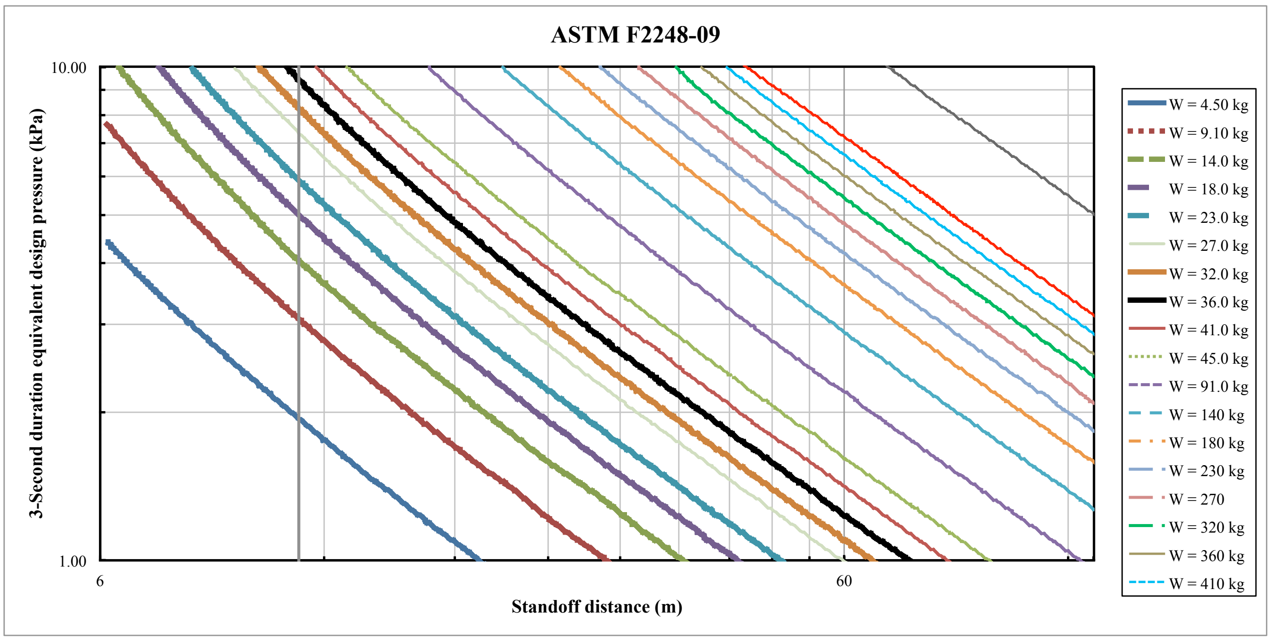


Figure 7: 3 second equivalent pressure ($q$) versus Stand off distance (SD) versus Charge weight ($w$)

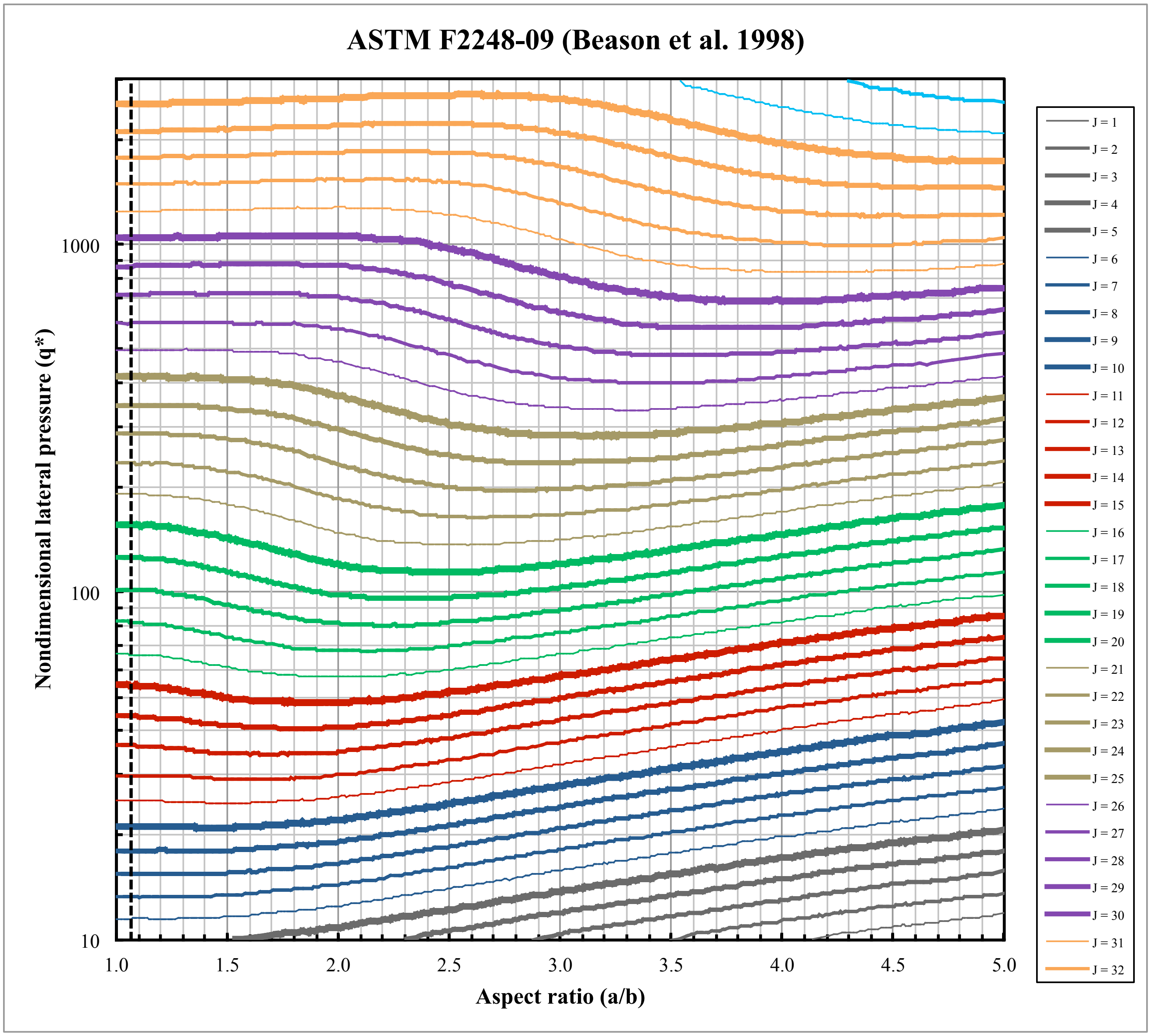


Figure 8: Non dimensional lateral load ($\hat{q}$) versus Aspect Ratio (AR) versus Stress distribution factor (Function) (J)