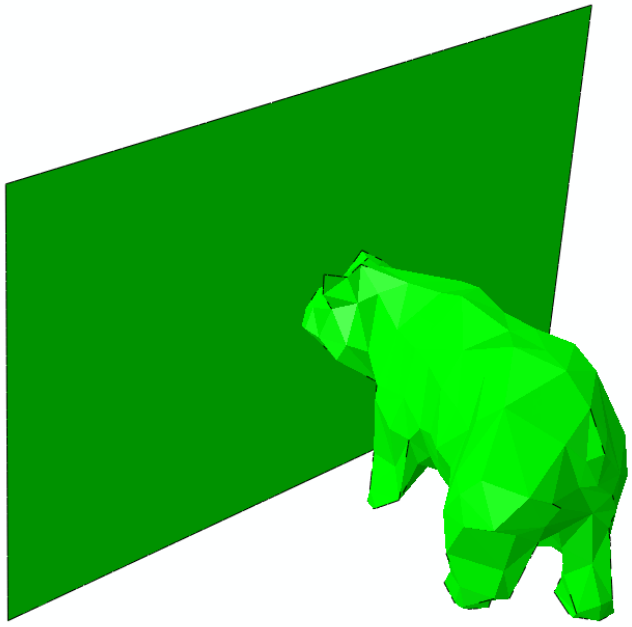
Impact Analysis of a Grizzly Bear on Glass Panels

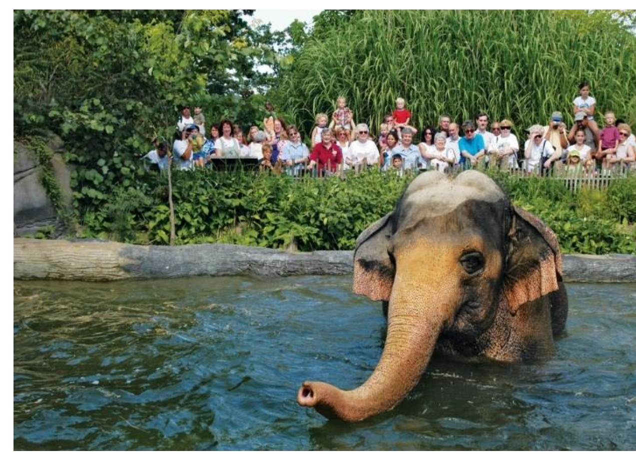


Kedar A. Malusare, Dr. Christian Stutzki and John Knowles,
Stutzki Engineering.

Introduction

Zoos in the United States of America

- Visiting Zoos is a popular pastime.
- Annual attendance[1] is 181 million !
  - More than annual attendance in NFL, NBA, NHL and MLB combined
  - Population of USA : 318.9 million so little more than half of US population (57%) visit zoos.
- Zoos are expanding and being more creative



Cincinnati Zoo

[1]https://www.aza.org/visitor-demographics/

Introduction

Zoos in the United States of America

Jacksonville Zoo

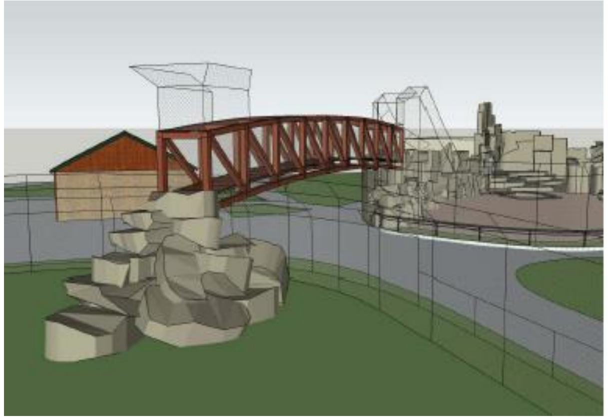
Philadelphia Zoo

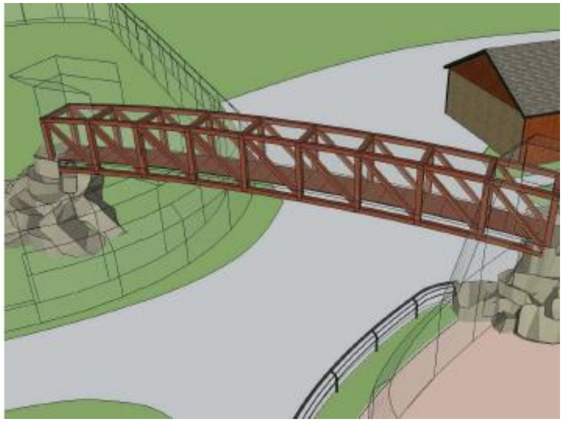
Denver Zoo

Henry Doorly Zoo-Omaha

Introduction

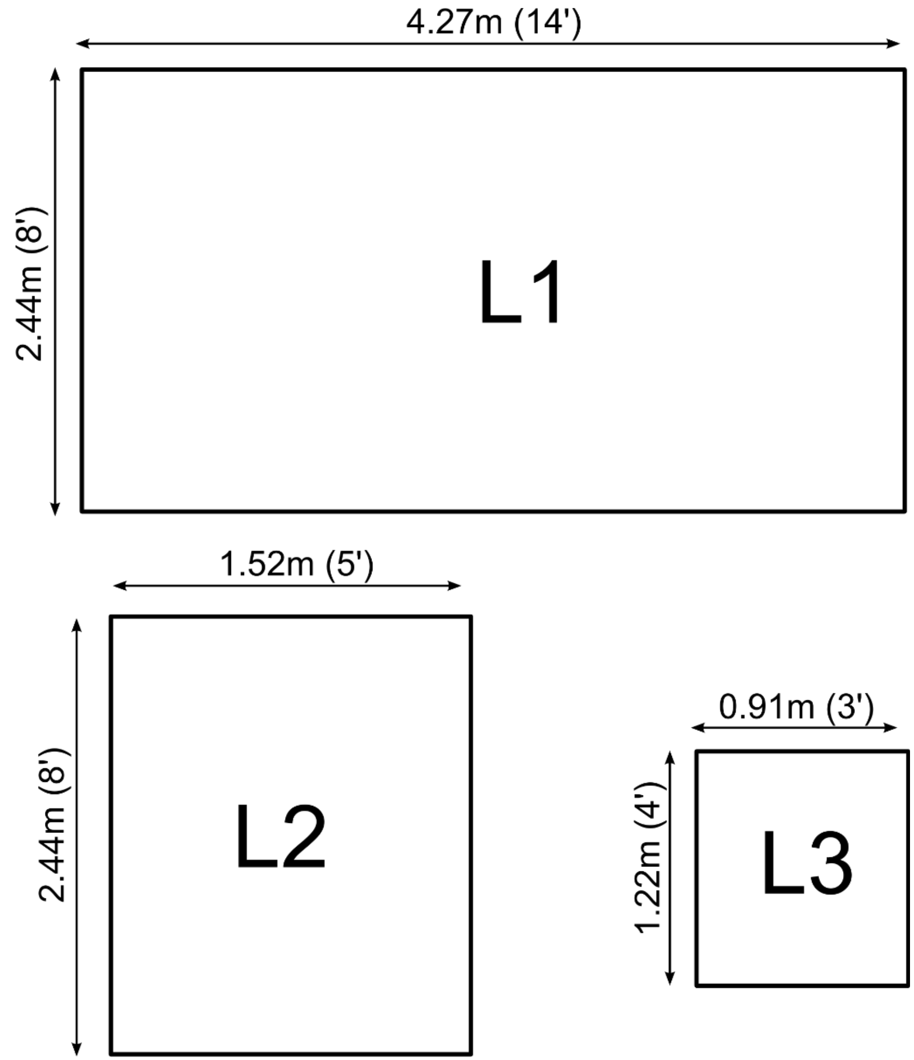
Bear enclosure – Wildwood Zoo, Marshfield, WI.





Introduction

Problem to be solved



Minimum glass thickness required to resist head on impact from a grizzly bear.

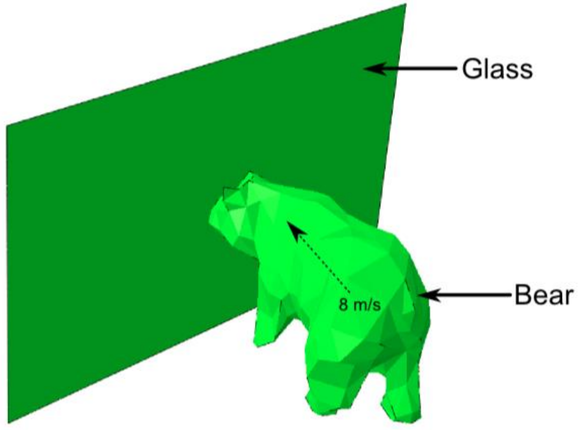
Outline

1. Introduction
2. Modeling Procedure
3. Calibration with the 'Shot Bag Test'
4. Finite Element Analysis of bear impact
5. Conclusions

Modeling Procedure

Dynamic Impact Analysis
(Abaqus explicit)

Provide velocity to the bear
and simulate impact



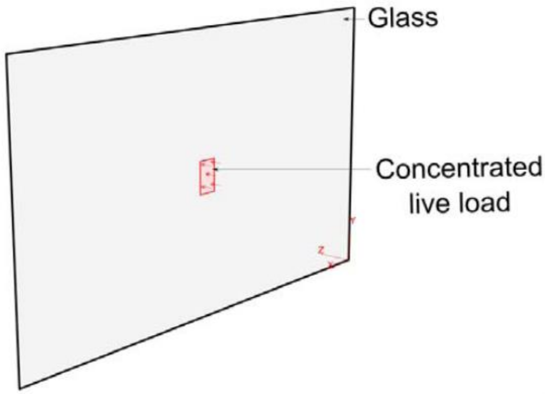
Static Analysis
(Abaqus standard)

Use Newton's equations

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2 \qquad F_{impact} = ma$$

$$v^2 = u^2 + 2as$$



Need for calibration of the impact modeling technique ?

Shotbag Test

1. Used for testing impact resistance

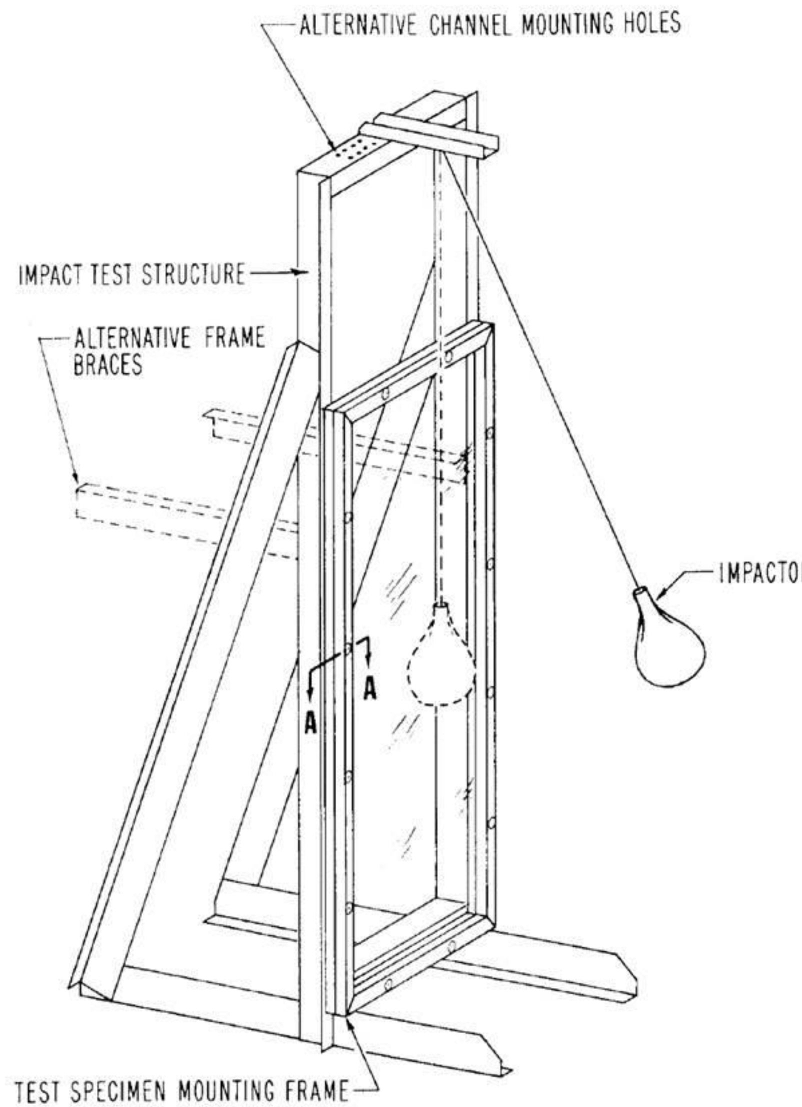
2. Impactor (shot bag) filled with hard/soft material, hits glass

3. Experimental results from paper[2]

Material properties

Material	E (psi)	ν
Glass	10400000	0.22
Shotbag	711	0.3

Velocity at impact: 3.86 mph



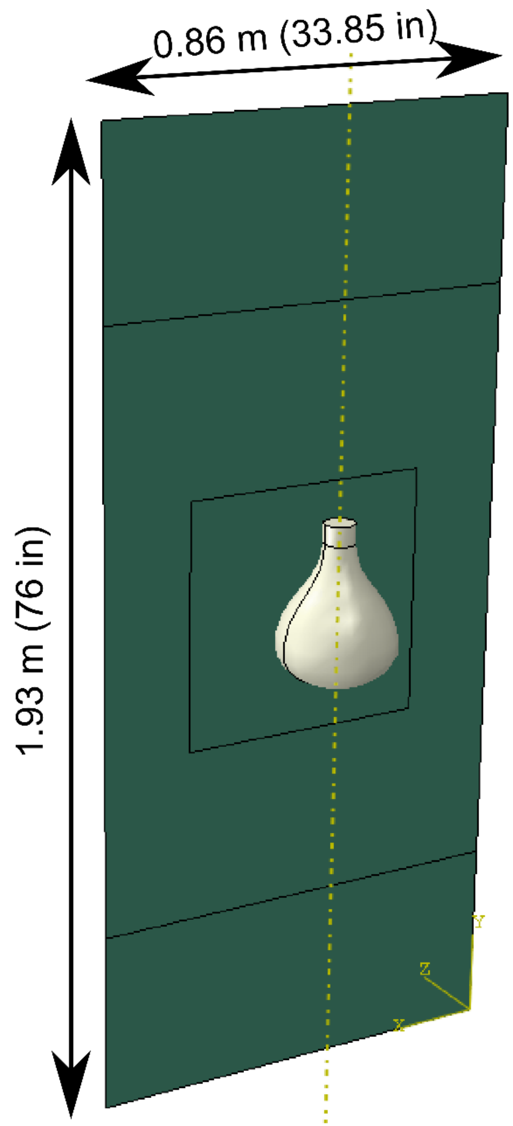
[2]Ray V. Foss and Takahiro Murakami et. al., Safety Glass Testing: Human Head Impactor Simulation by Dynamic Transient Analysis,

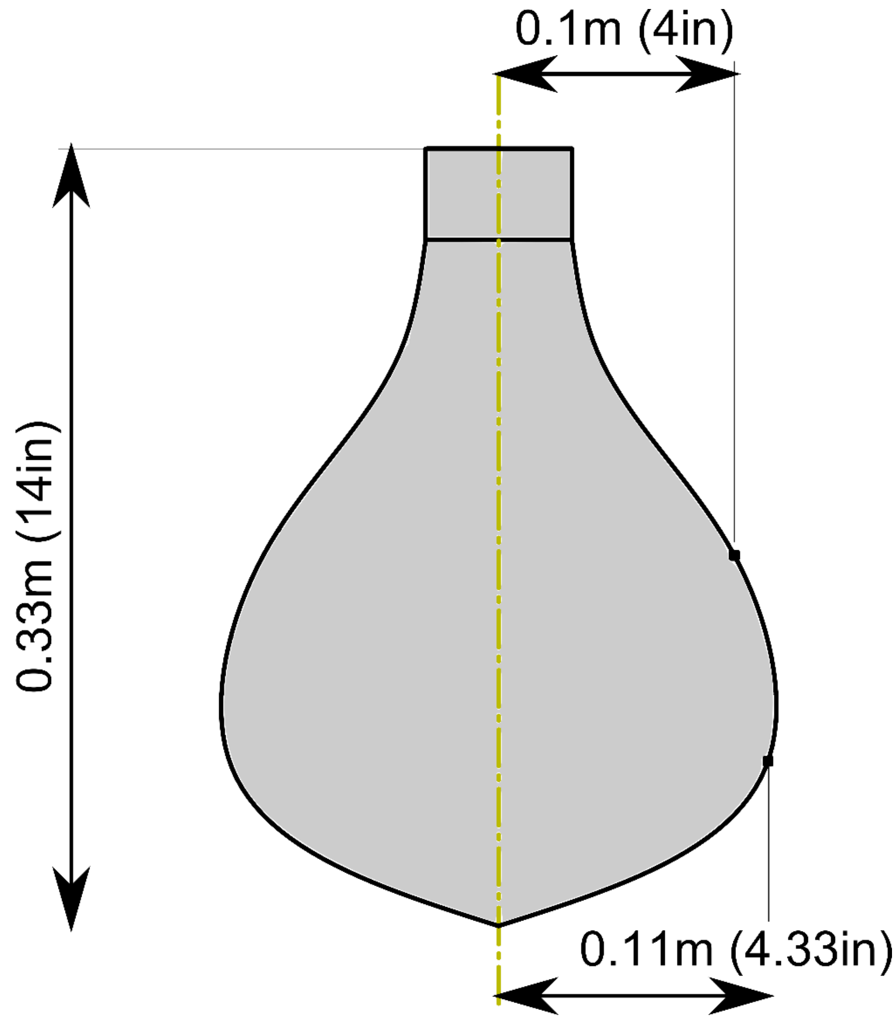
Shotbag Test

Video of shotbag test (ESG Glass)

Shotbag Test

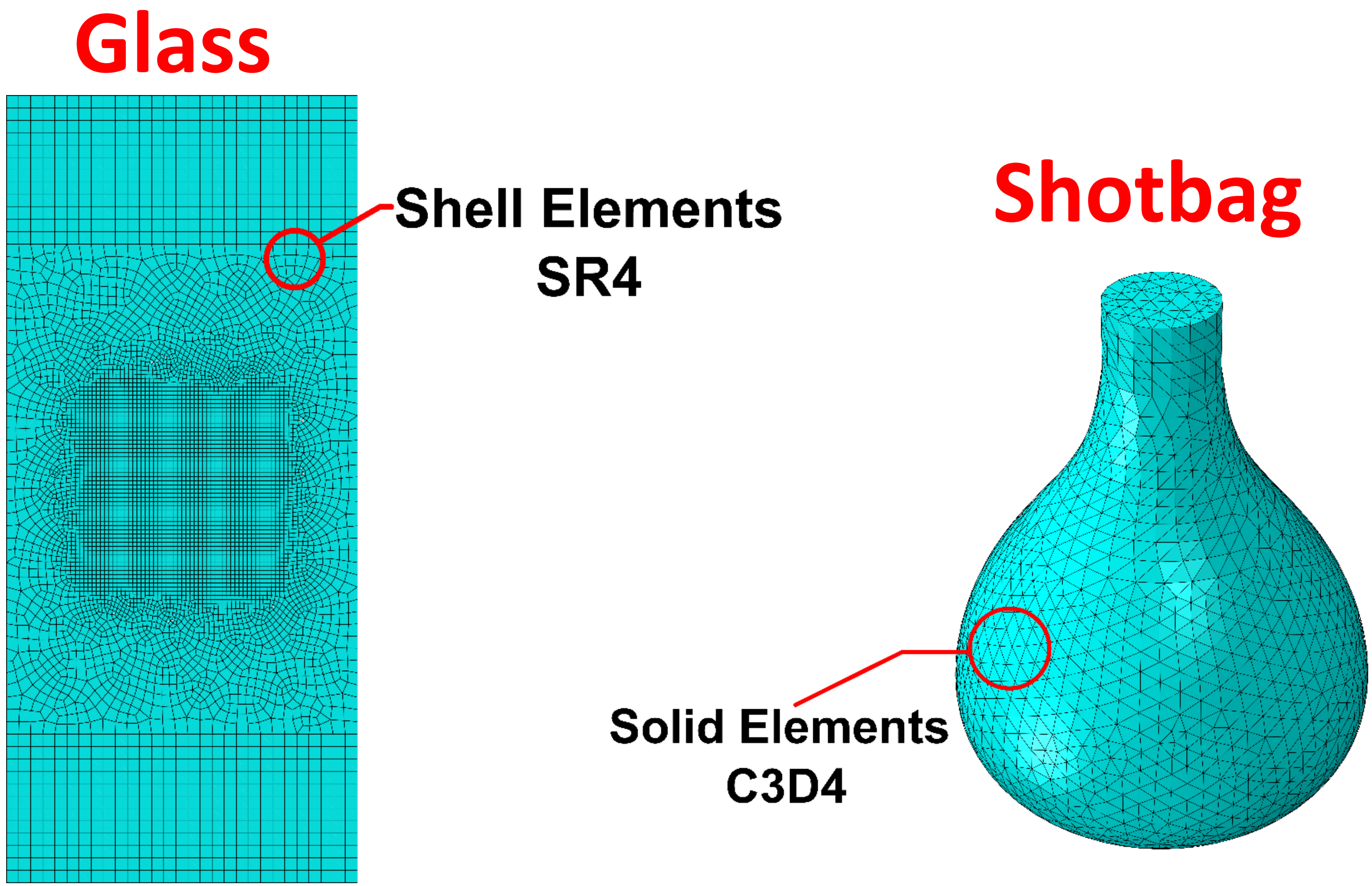
FEA Model





Shotbag Test

Elements

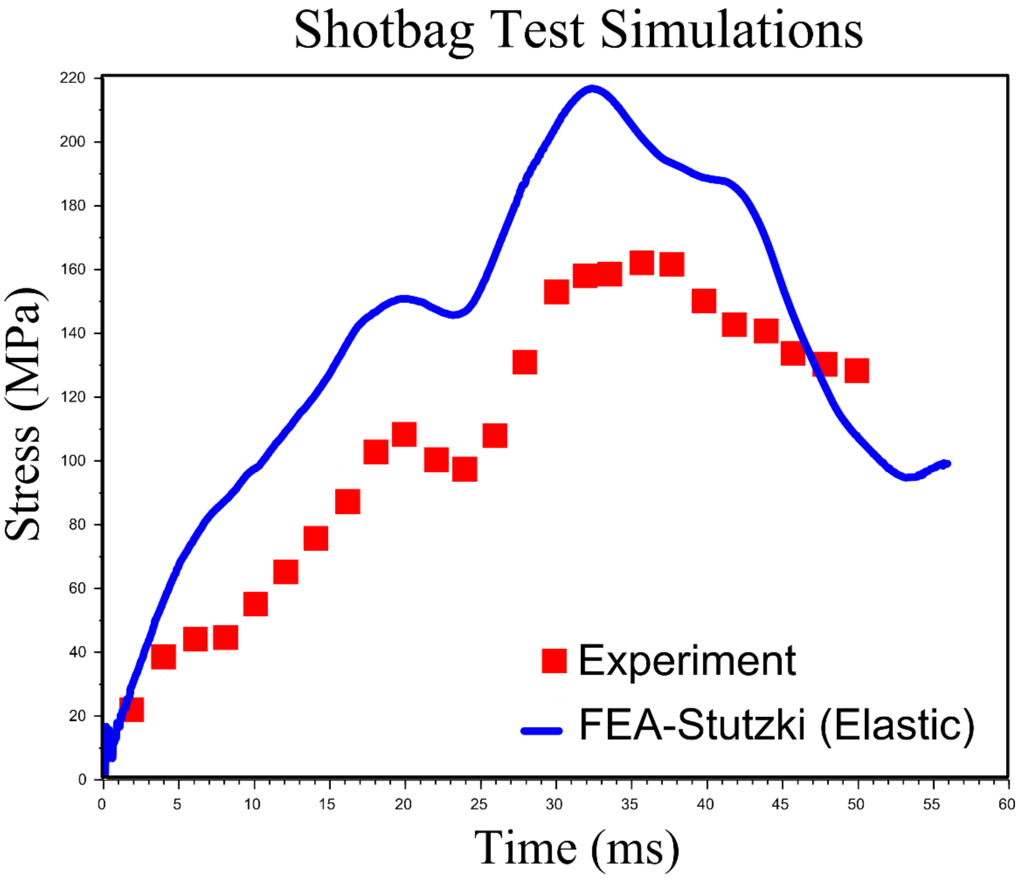


SR4	4-node doubly curved thin or thick shell, reduced integration, hourglass control, finite membrane strains
C3D4	A 4-node linear tetrahedron

Shotbag Test

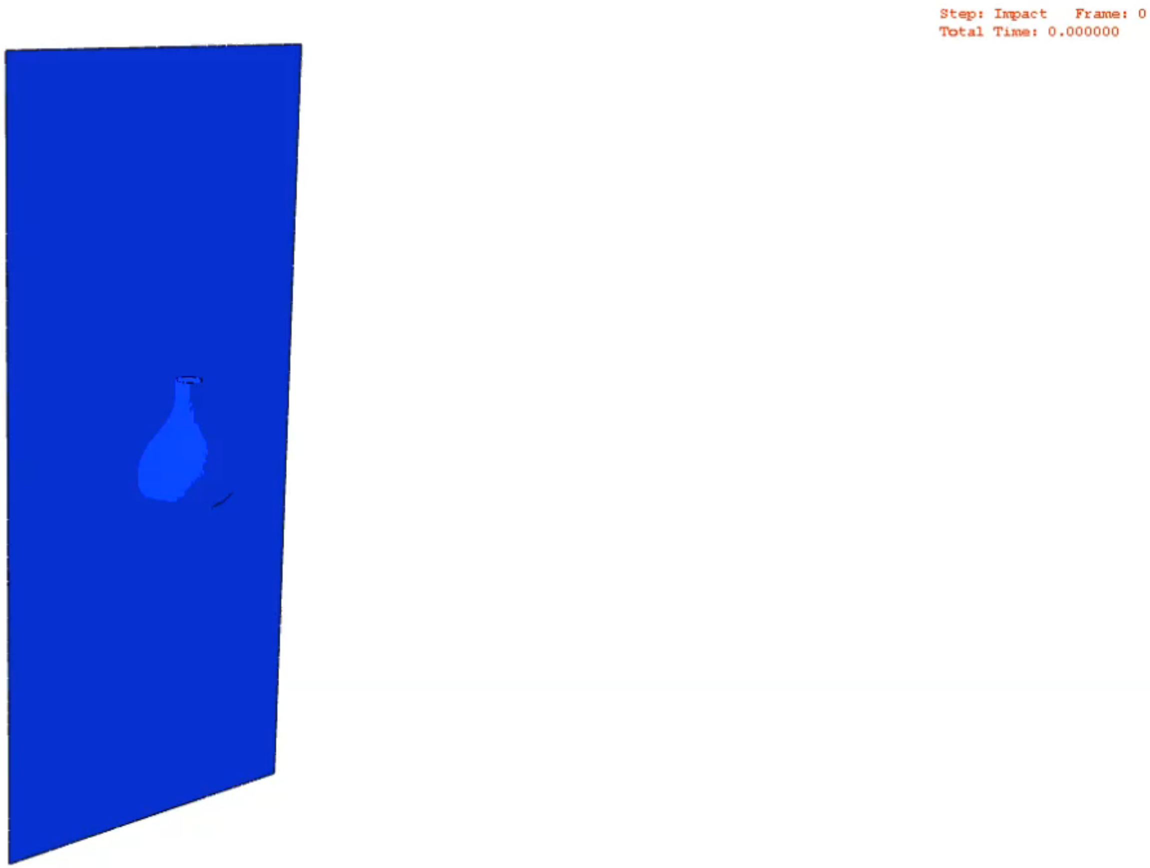
Results

- Captured the shape of the experimental data
- Stresses are higher
- Shape of the shot bag
- Elastic collision



Shotbag Test

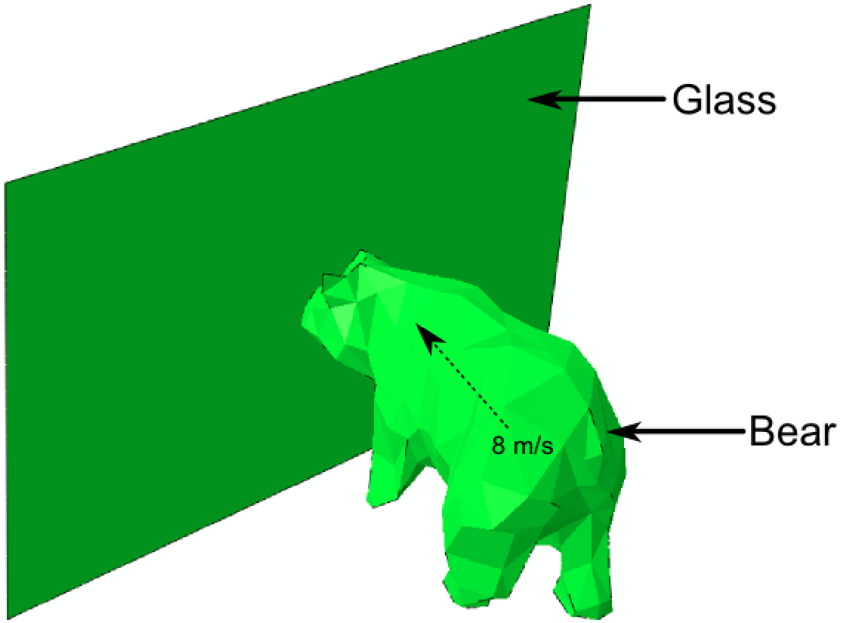
Video



FEA of bear Impact

Modeling of the Bear

- Solid CAD model
- Tetrahedron elements
- Velocity of bear was 18 mph
- Weight of the bear was 800 lbs.
- Mass density is about 0.0127 lb/in^3

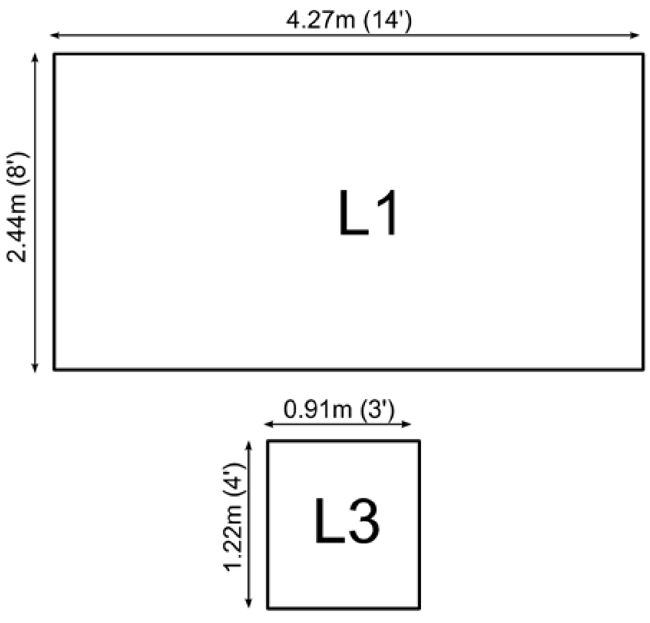


Material	E(psi)	ν	Y(psi)
Bear	711	0.3	1060

FEA of bear Impact

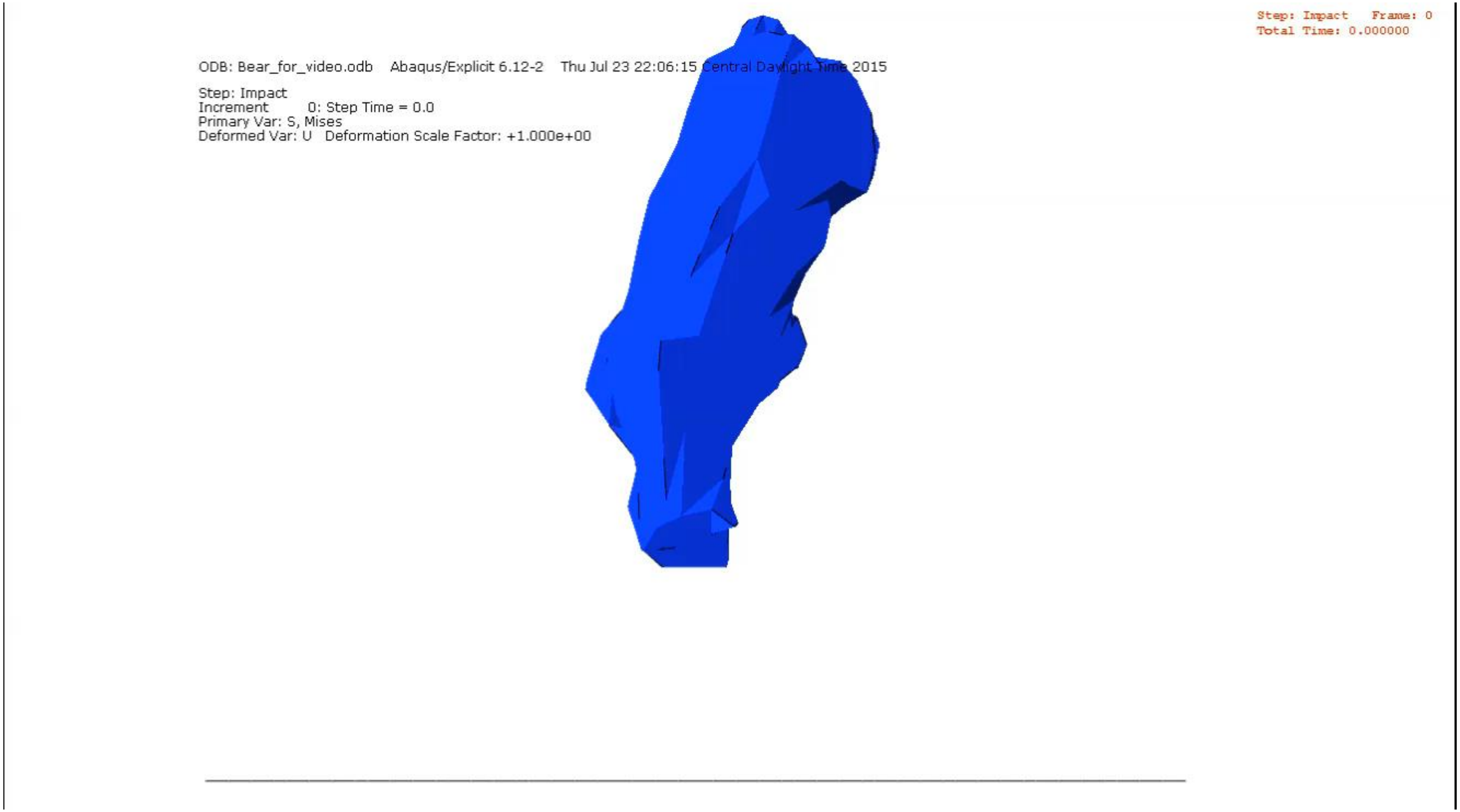
Video

- Modeled with shell elements
- Effective thickness : 1.89”
- The largest and the smallest pieces of the glass were modeled
- Four side supported



FEA of bear Impact

Video



FEA of bear Impact

Dynamic Impact Analysis (Abaqus explicit)

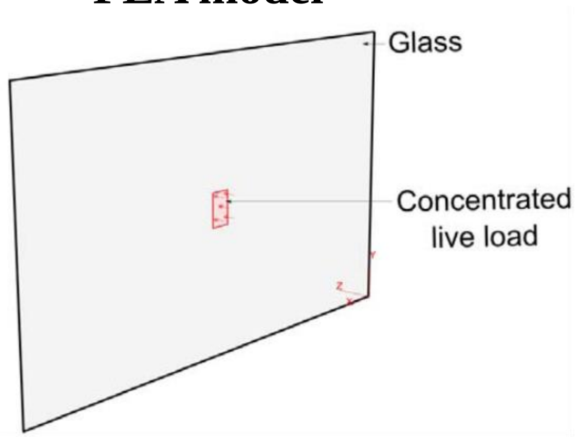
- Analysis was run for 1/10th of a sec

Lites	Stress (psi)	Stress (psi)	Deflection (in)	Limit Deflection (in)
L1	1015	6750	0.080	0.95
L3	3190	6750	0.040	0.47

FEA of bear Impact

Static Analysis (Abaqus Standard)

FEA model



Newtons first law

$$F_{impact} = ma$$

Equations of motion

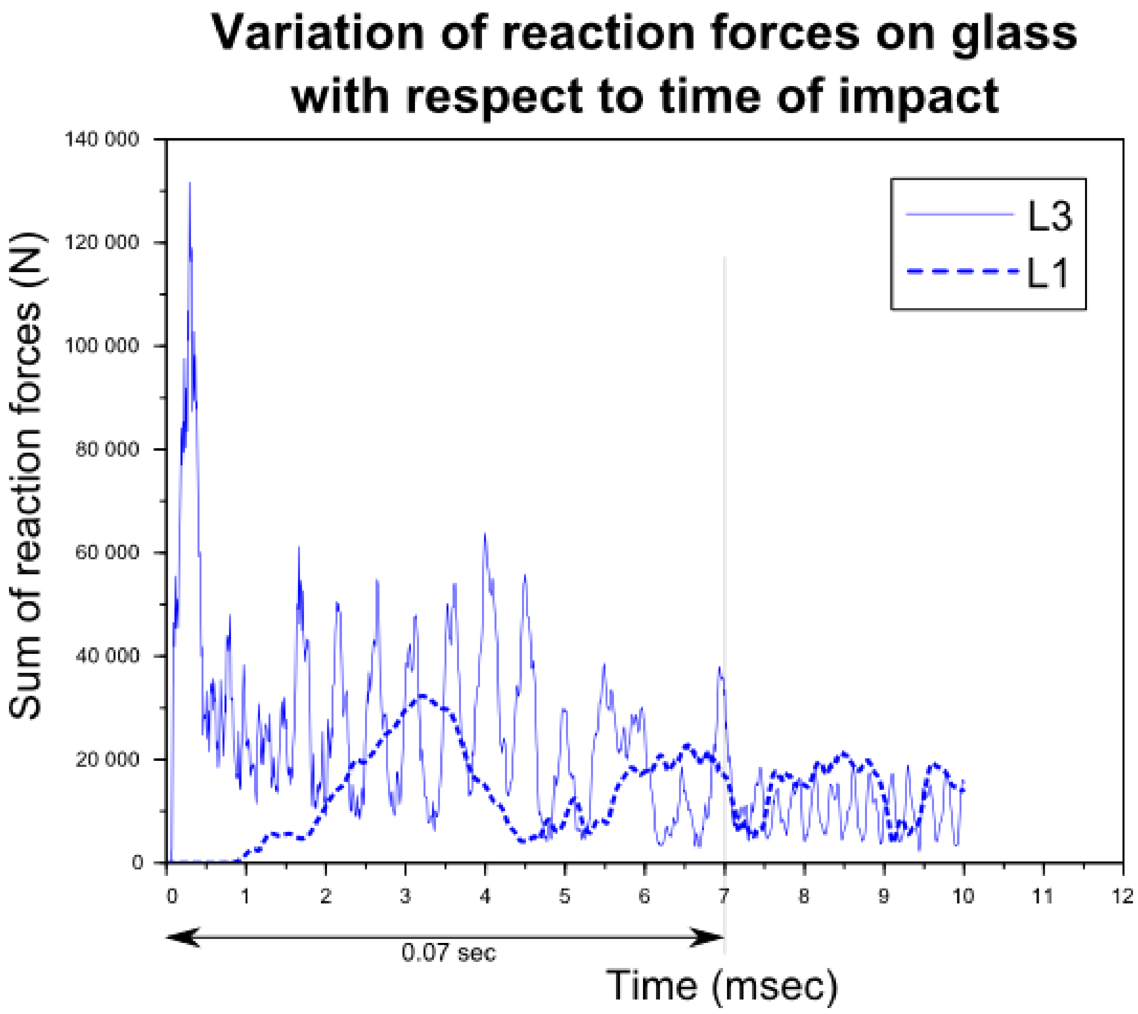
$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

HOW LONG DOES THE IMPACT LAST ???

FEA of bear Impact



HOW LONG DOES THE IMPACT LAST ??? **0.07 secs !**

FEA of bear Impact

$$F_{impact} = ma$$

Calculation of the Impact force for static FEA analysis

Calc for L1

$v1 := 0 \frac{m}{s}$

$u1 := 8 \frac{m}{s}$

$t1 := 0.070 sec$

$a1 := \frac{(v1 - u1)}{t1} = -114.286 \frac{m}{s^2}$

$mass := 365 kg$

$force1 := mass \cdot a1 = -4.171 \times 10^4 N$

Calc for L3

$v2 := 0 \frac{m}{s}$

$u2 := 8 \frac{m}{s}$

$t2 := 0.070 sec$

$a2 := \frac{(v2 - u2)}{t2} = -114.286 \frac{m}{s^2}$

$mass := 365 kg$

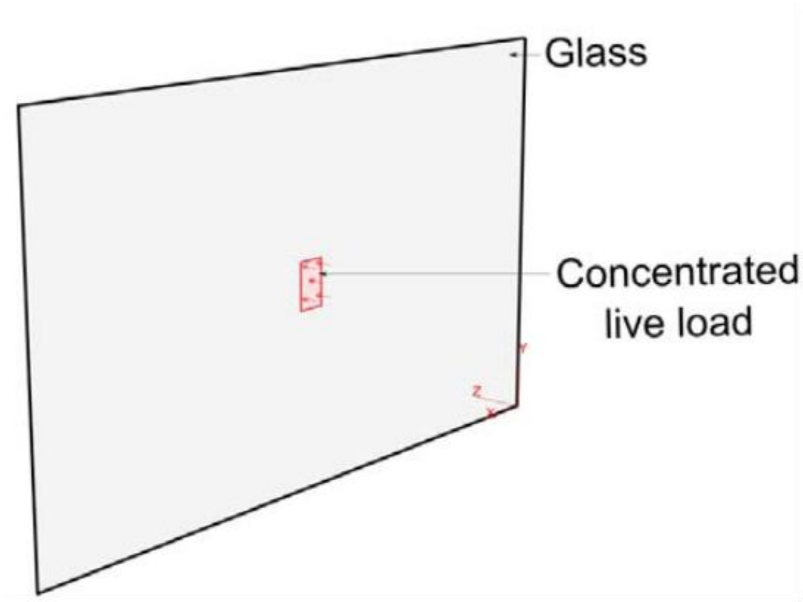
$force2 := mass \cdot a2 = -4.171 \times 10^4 N$

T= 0.07 secs

$$v = u + at$$

$$F_{impact} = ma$$

FEA of bear Impact



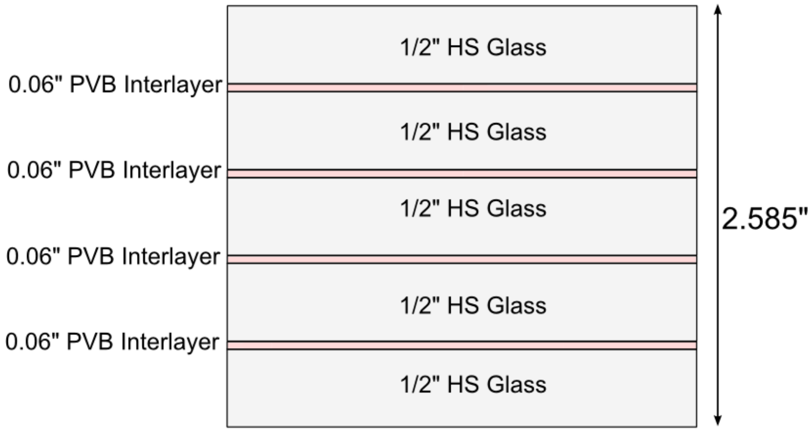
$$F_{impact} = ma$$

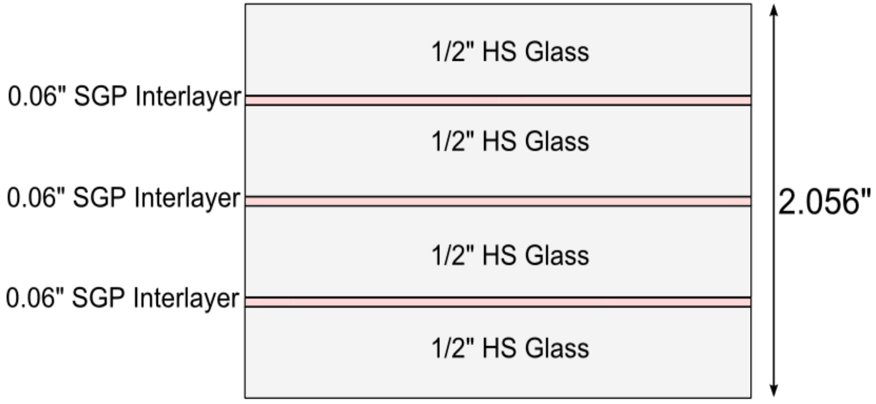
Results

Lites	Stress (psi)	Stress (psi)	Deflection (in)	Limit Deflection (in)
L1	4787	6750	0.236	0.95
L3	3368	6750	0.040	0.47

Conclusions

- A methodology for impact calculation was developed and calibrated with results
- Glass panels were analyzed for animal impact using dynamic and static calculations





Thank you