



FIRE  **IMPACT**  **BLAST**
REPAIRS AFTER EXTRAORDINARY EVENTS

Wednesday
November 9

11:15 AM – 12:00 PM

2022 ICRI Fall Convention | Atlanta, GA | November 7-9

Bomb Blast Primer



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Principal
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Woodstock, Georgia



The ideas expressed in this ICRI hosted webinar are those of the speakers and do not necessarily reflect the views and opinions of ICRI, its Board, committees, or sponsors.

Today's Presenter

- **Scott L Weiland PE SE**
 - Principal, Innovative Engineering Inc.
 - Education
 - BSCE **University of Michigan**
 - Graduate Studies in **Structural Dynamics:**
 - San Jose State University
 - Georgia Institute of Technology
 - **Security Engineering:** USACE Protective Design Center
 - **Interagency Security Committee (ISC)** Risk Management Process: ARA
 - Counter Terrorism Workshop for Improvised Explosive Devices (IED) and Vehicle-Borne Improvised Explosive Devices (VBIED) - **Department of Homeland Security (DHS)**
 - Registration: PE in 40 States + PR & GU
 - **26 Years Physical Security Engineering**



Learning Objectives

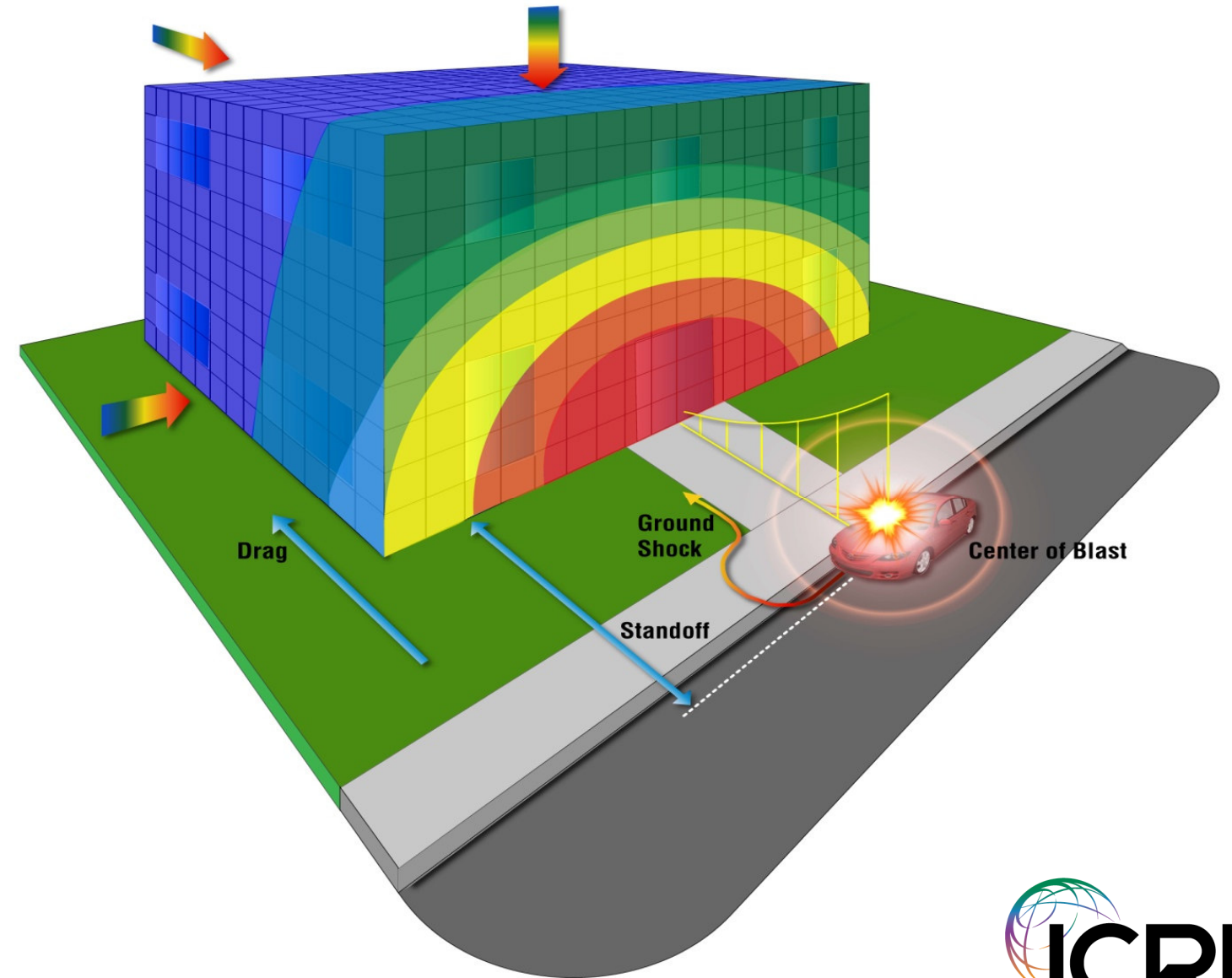
- **Blast Theory**
- **Blast Analysis**
- **Blast Design**
- **Progressive Collapse**

Explosives

- **Explosion**
 - Sudden Release of Energy
 - Audible Sound
- Types of Explosions
 - **Expansion**
 - Bursting Pressure Vessel
 - Boiling Liquid Expanding Vapor Explosions (BLEVES)
 - Rapid Phase Transitions (RPT's)
 - **Oxidation**
 - Vapor Cloud Explosions
 - Dust Explosions
 - **Condensed Phase Explosion (High Energy Explosives)**

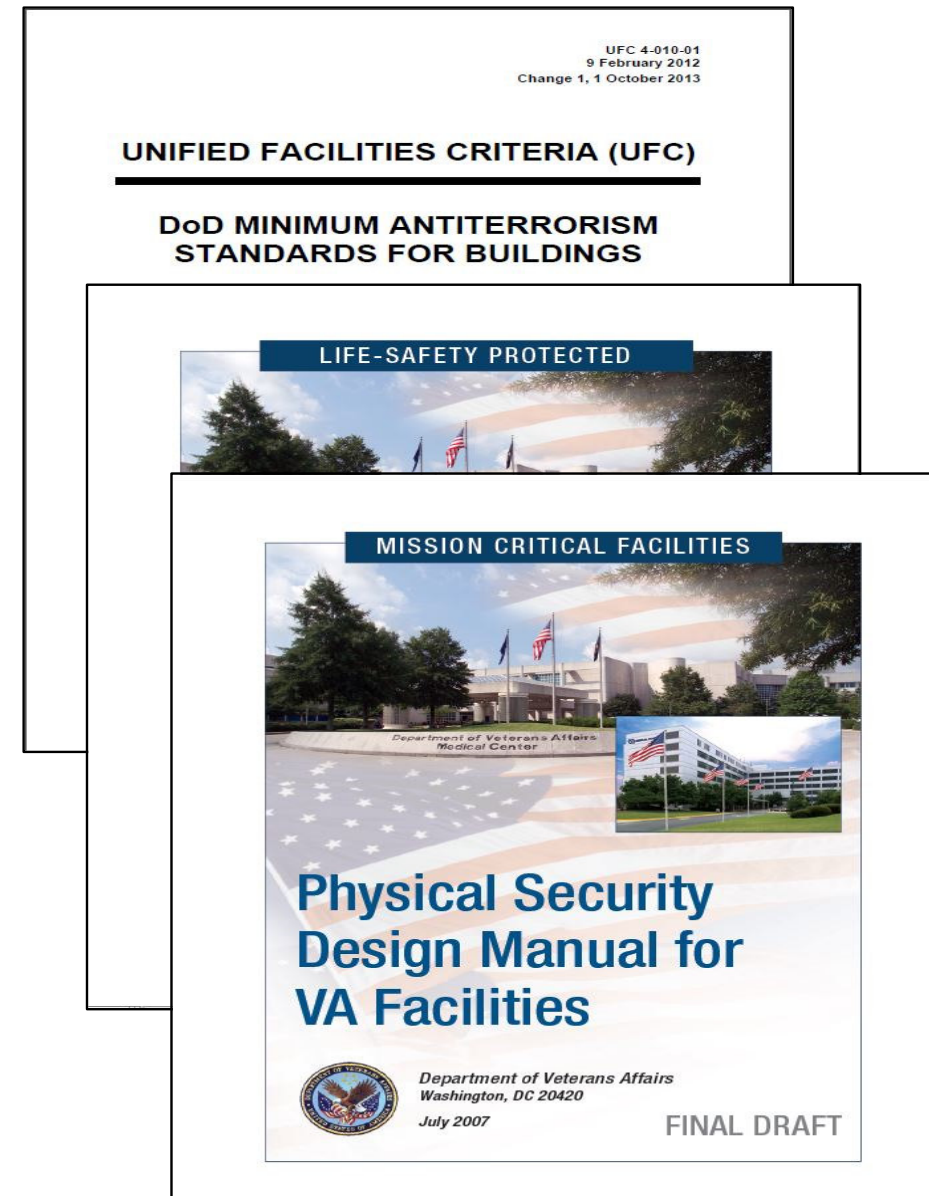
Blast Theory - Definitions

- **Aggressor**
- Tactic – Stationary Bomb
- **Standoff**
- Shock Wave
- **Reflective Pressure**
- **Side-On/Incident Pressure**
- Dynamic (Blast Wind) Pressure
- Hardening
- Asset



Risk Reduction Criteria

- Prominent Design Criteria
 - GSA Facility Security Requirements for Explosive Devices Applicable to Facility Security Levels III and IV, GSA's Interpretation of the Interagency Security Committee (ISC) Physical Security Criteria. (FOUO)
 - DoD Minimum Antiterrorism Standards for Buildings, UFC 4-010-01
 - VA Physical Security Design Manuals (PSDM) for Life Safety & Mission Critical Facilities
- Minimum Standards
- Need to be adapted to private facilities



Pressure Shock Wave



Blast Theory – Pressure Wave



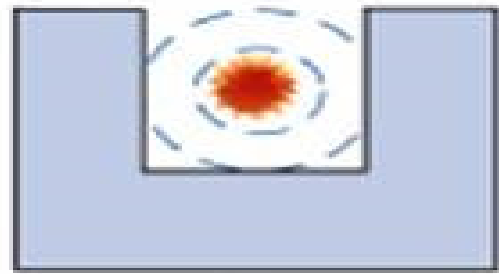
- Supersonic pressure wave caused by detonation
- Like water wave including reflections and refractions and reformation

Blast Theory – Vehicle Bomb

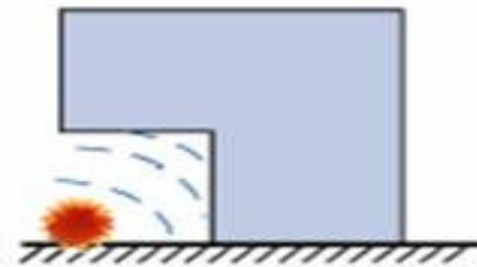


- Surface Burst (VBIED)
- Pressure Radiates
- Reflected Pressure
- Refracted Pressure
- Side-On Pressure

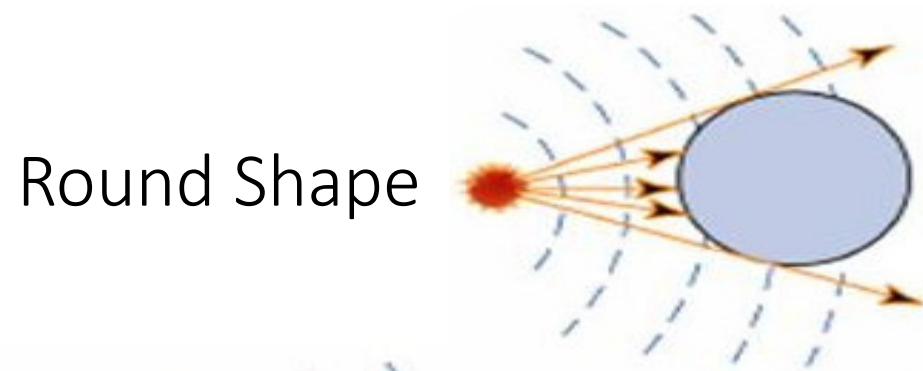
Blast Theory - Shapes That Affect Blast



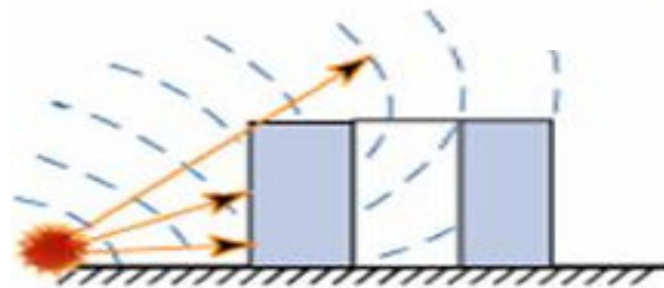
Re-entrant corners



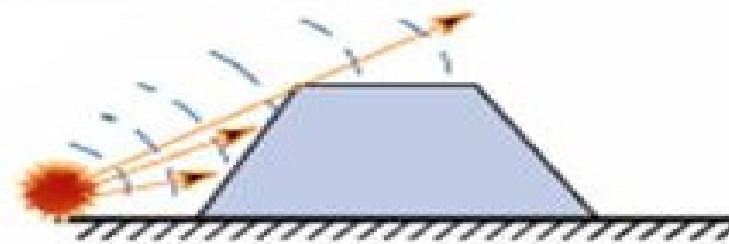
Overhang



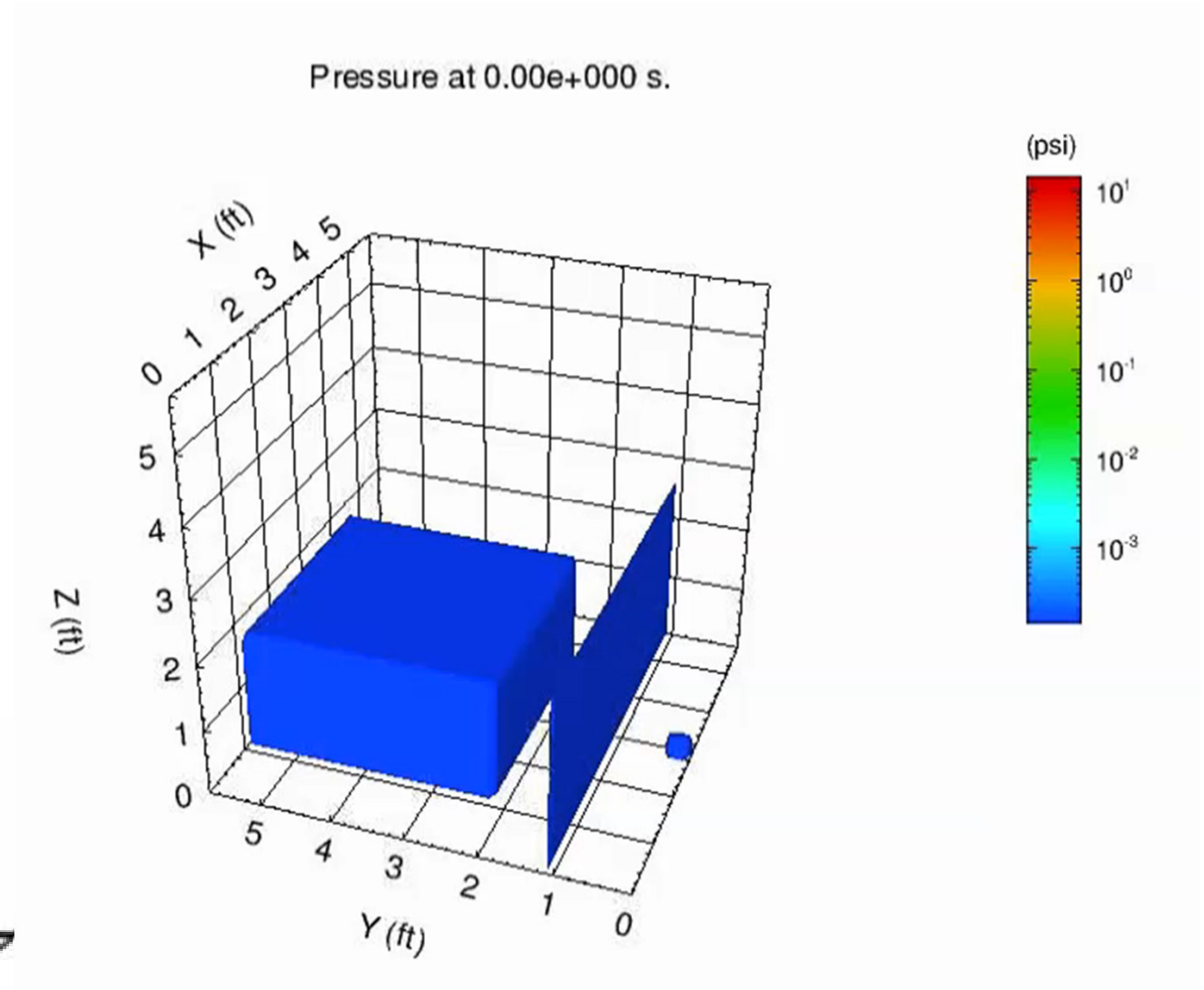
Round Shape



Blast Wall

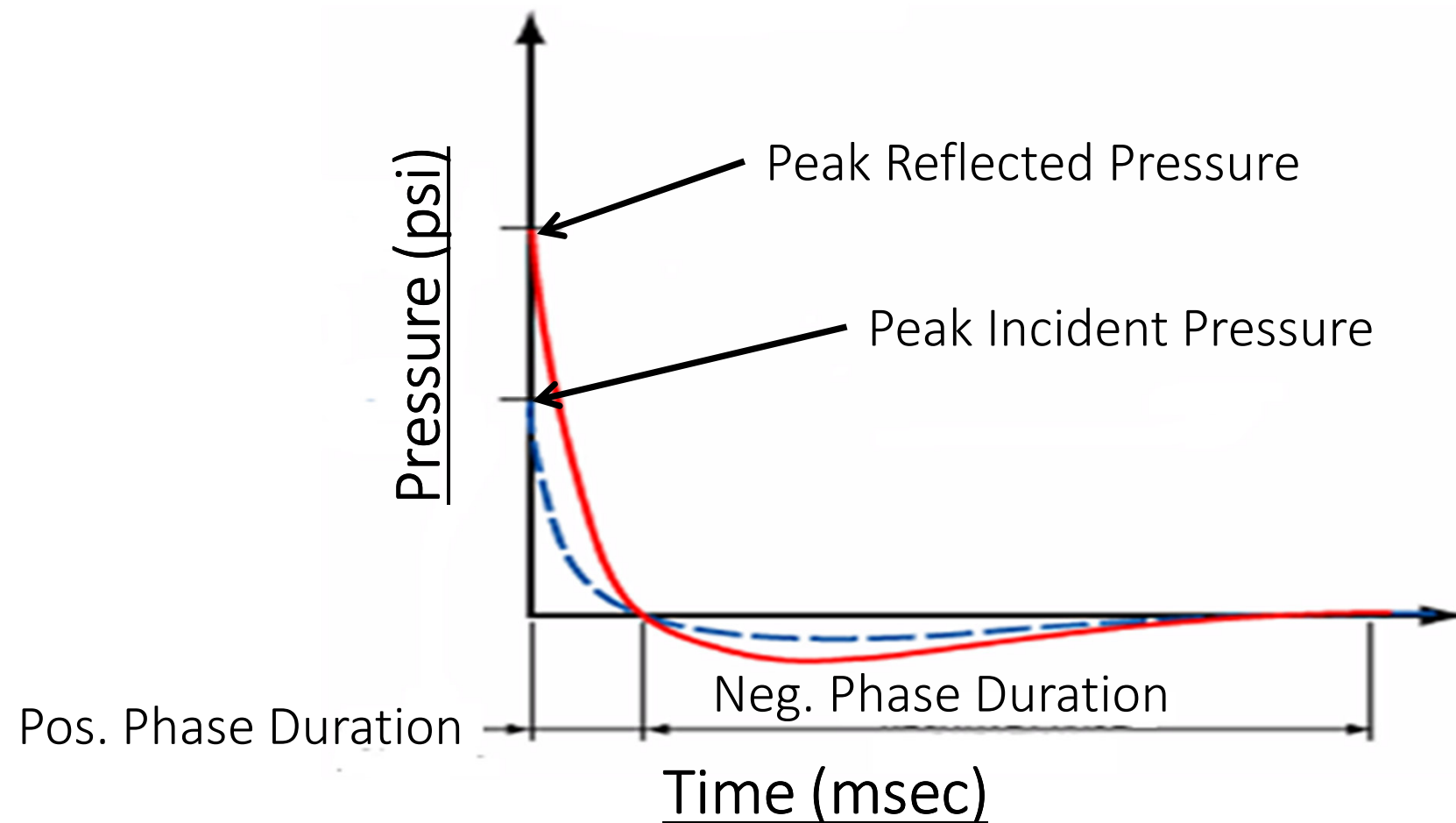


Berm



Blast Wall - CFD

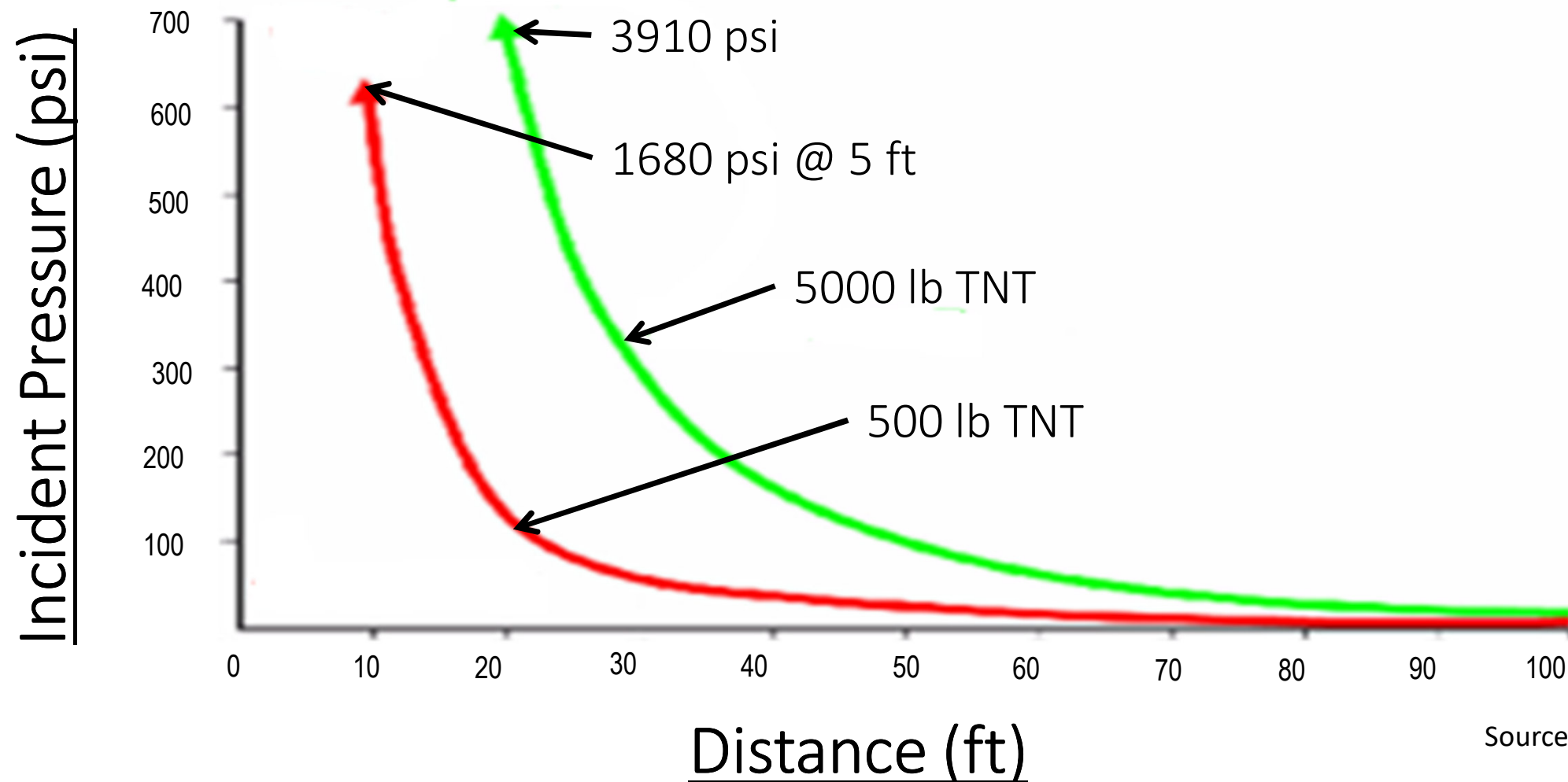
Blast Theory – Time History



Source: FEMA 427

- Pressures decay exponentially with time.
- Dynamic, non-linear, time history analysis.

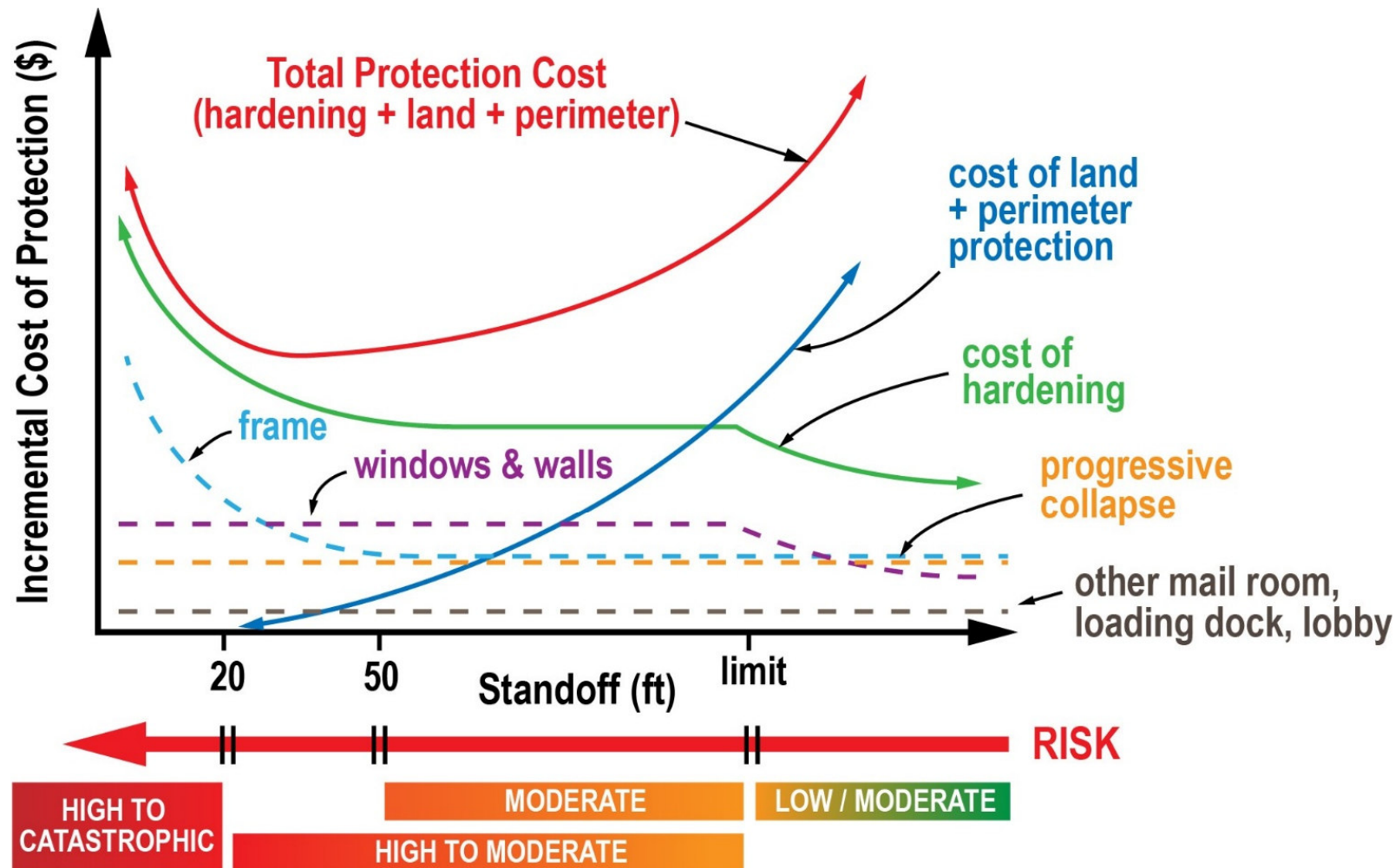
Blast Theory - Distance



Source: FEMA 427

- Pressures decay with the cube root of the distance from the explosion.

Blast Theory - Optimum Standoff



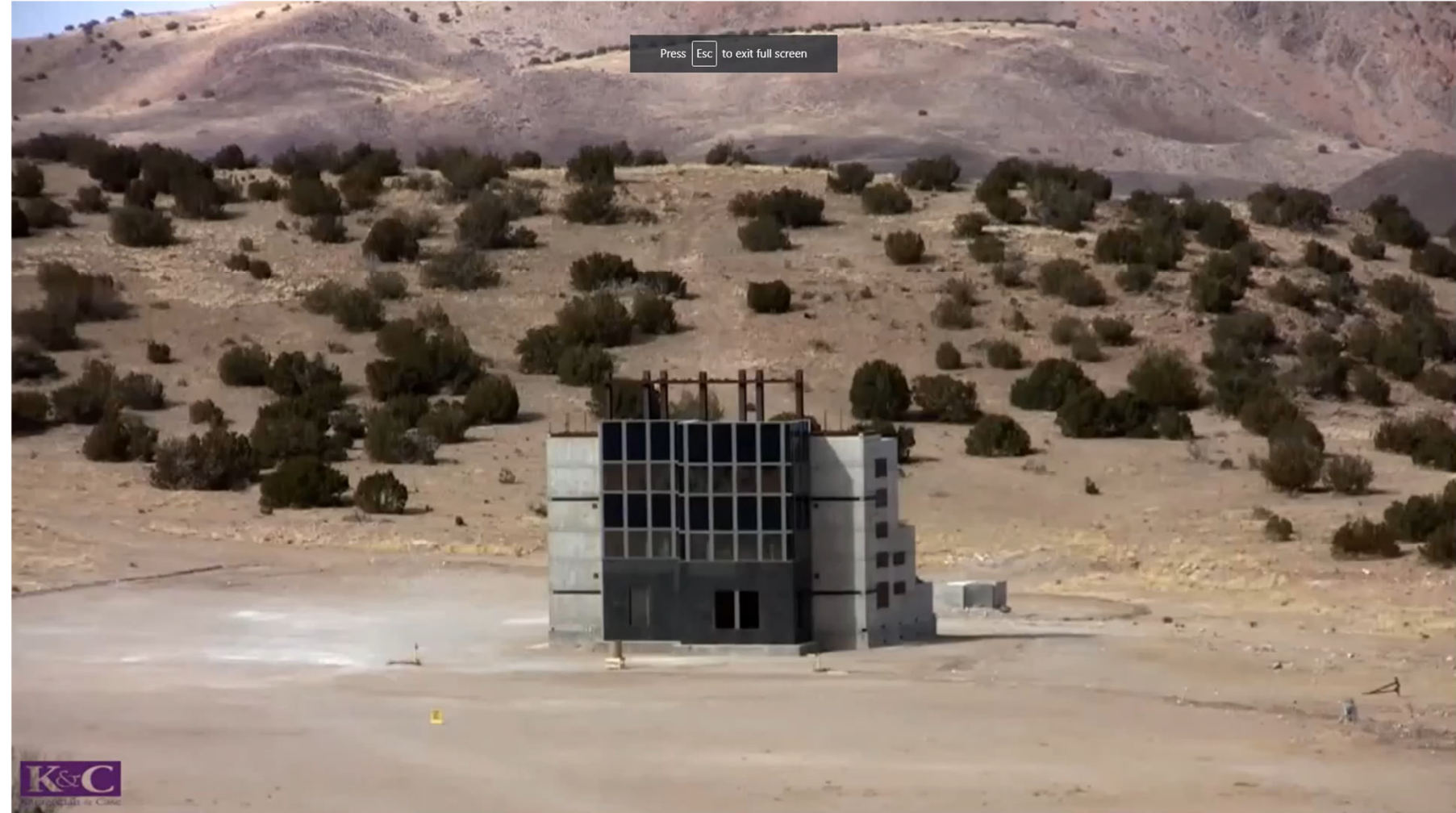
Plots showing relationships between cost of upgrading various building components, standoff distance, and risk

- **Optimum Stand-Off**
 - More Stand-Off = Less Hardening, More Land
 - Less Stand-Off = More Hardening, Less Land

Source: FEMA 427

Blast Theory - Explosion

- Karagozian & Case, Inc.
- State Department
- Retrofit curtainwall system



Blast Theory - Explosion



- Shock Wave
- Reflected Pressure
- Rebound
- Side-On Pressure

Blast Theory - Explosion

- Shock Wave
- Reflected Pressure Wave
- Rebound



Blast Design – Conservation of Energy

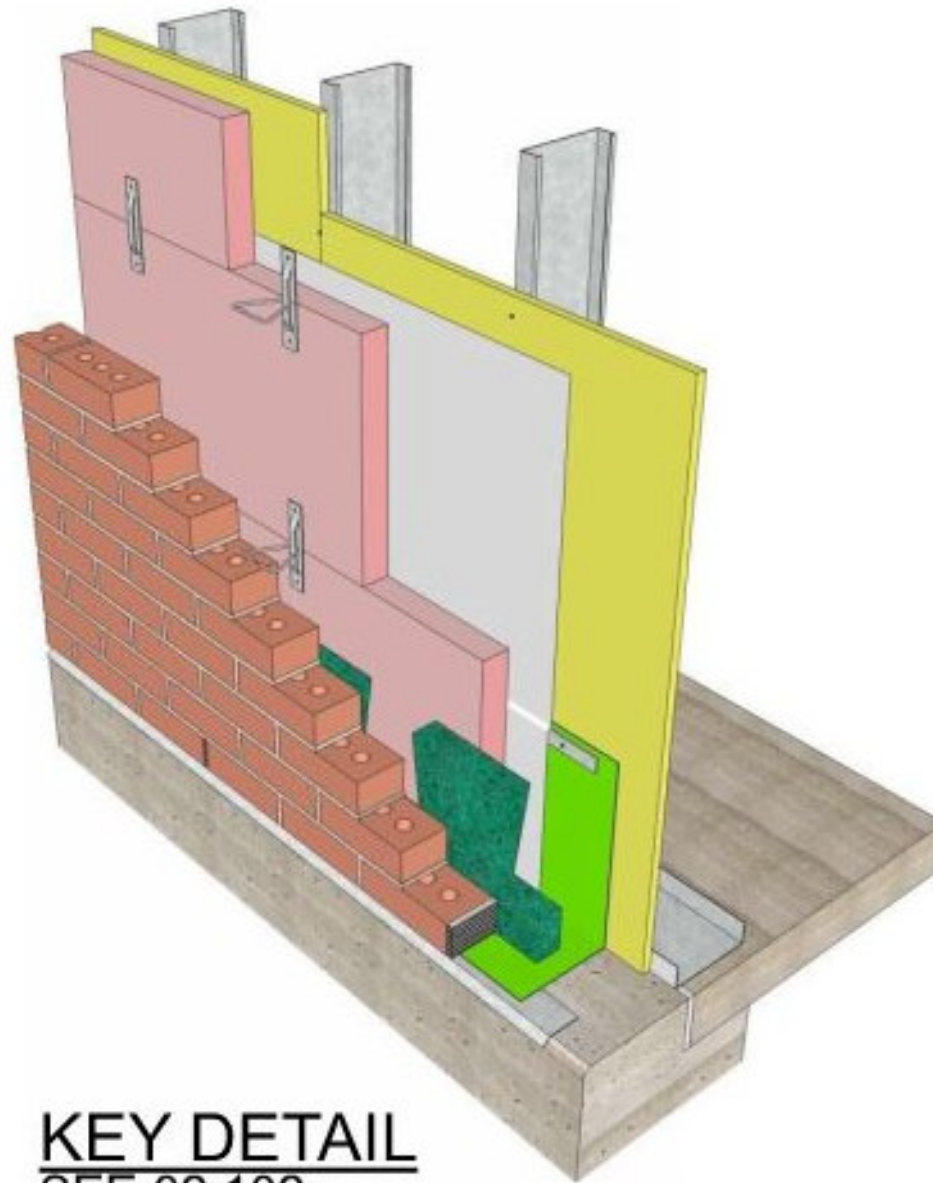
Energy Equation

- $W_P = W_K + W_S$
 - $W_P = \text{Blast Energy}$
 - $W_K = \text{Kinetic Energy}$
 - $W_S = \text{Strain Energy}$



Blast Design – Kinetic Energy

$$W_K = \frac{m_e * V^2}{2}$$

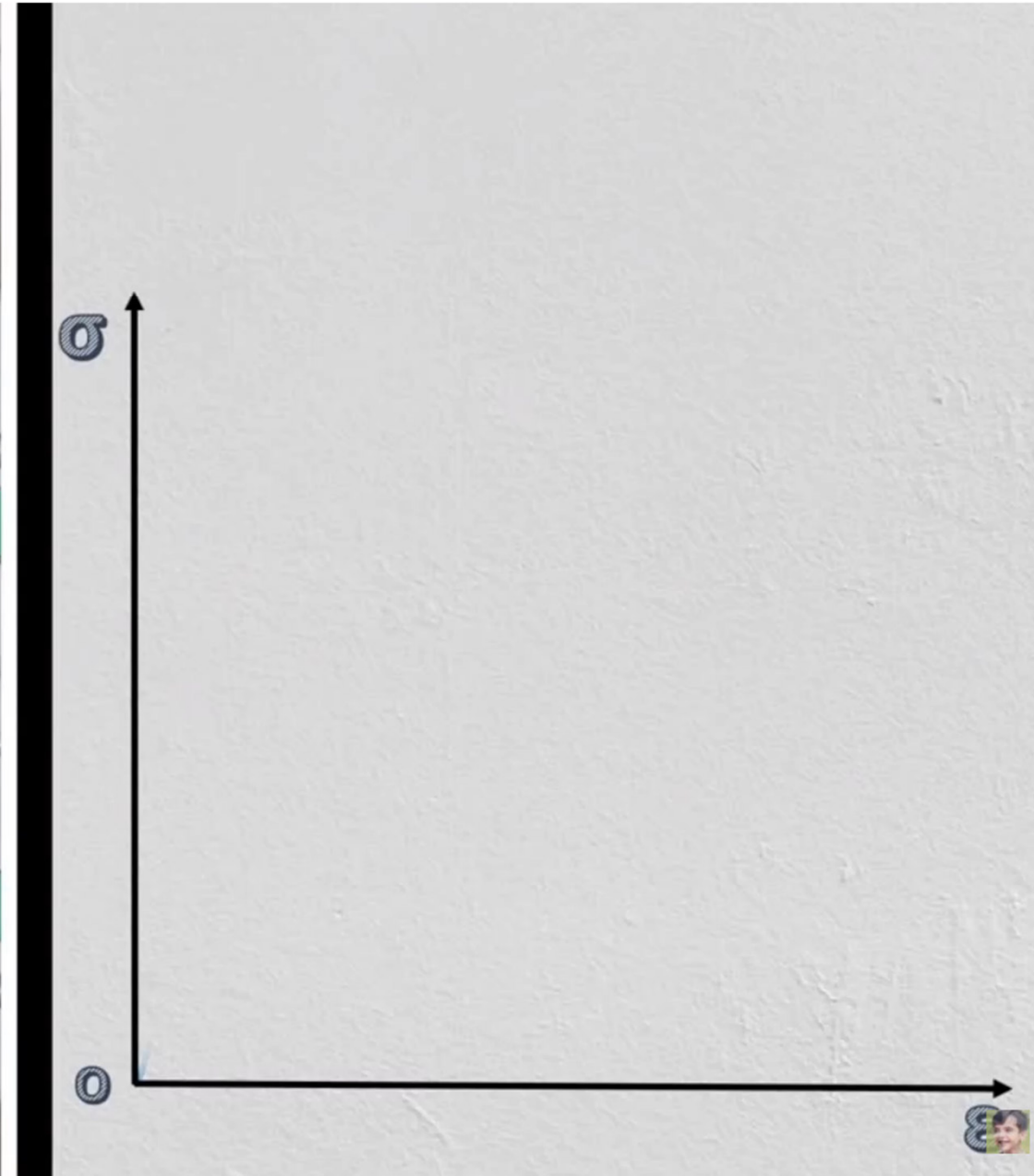
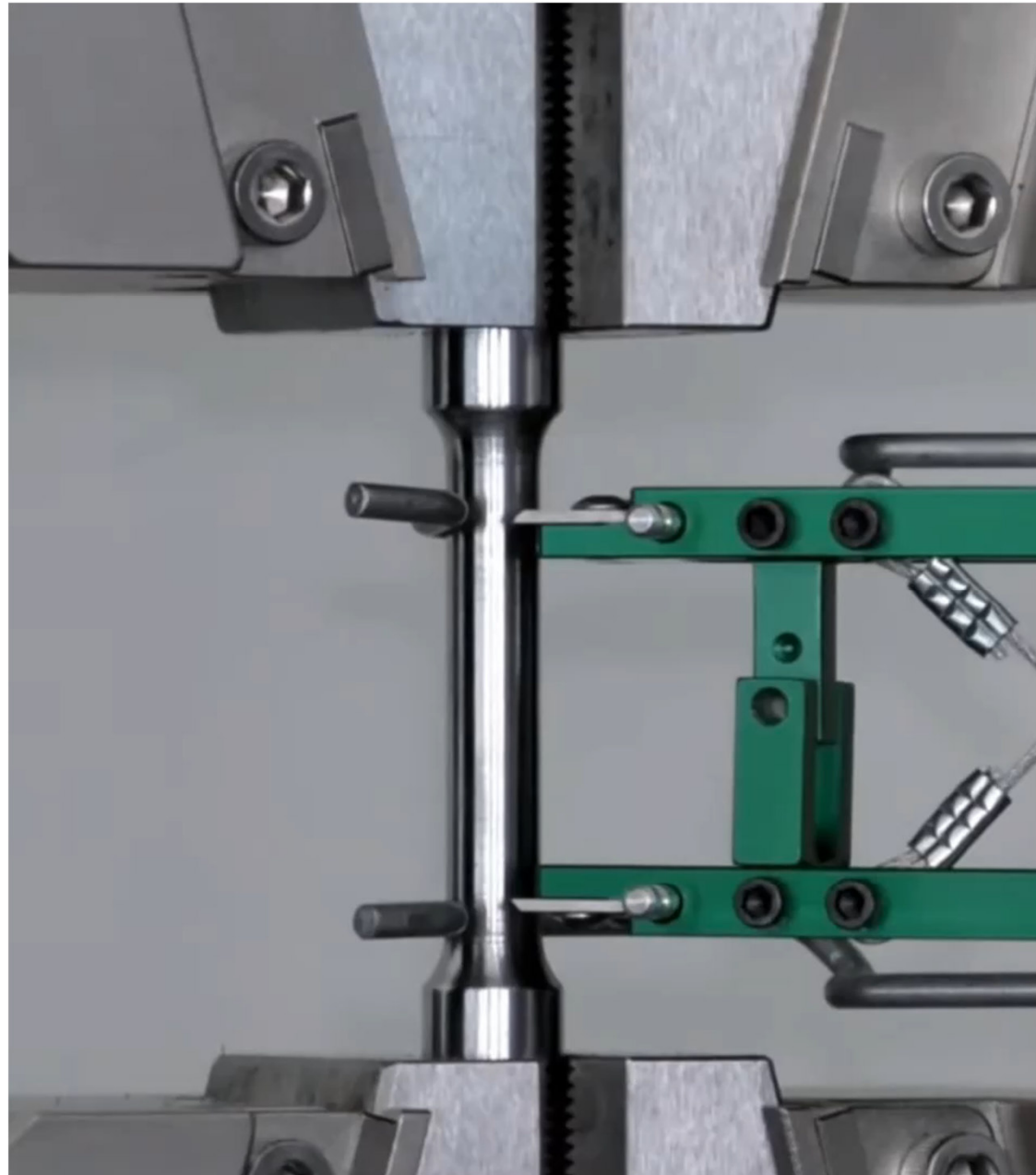


KEY DETAIL
SEE 02.102

Masonry Wall Institute



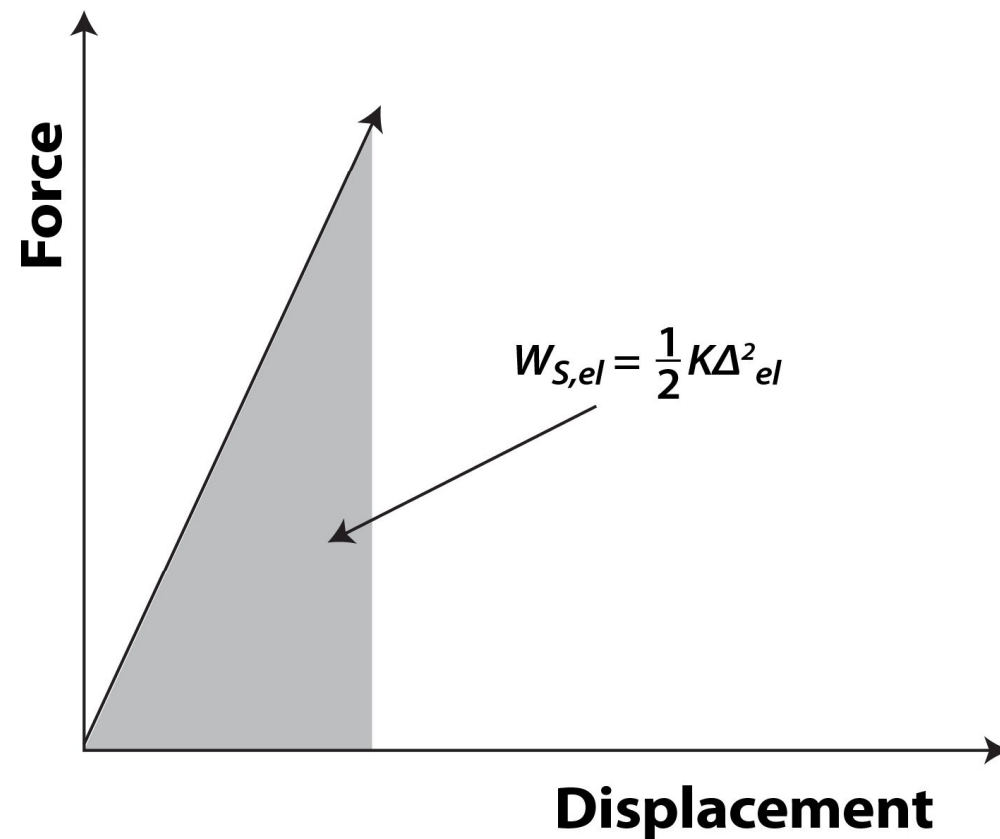
Blast Design – Strain Energy – Ductility



- Regions
 - Elastic
 - Plastic
- Area = Strain Energy

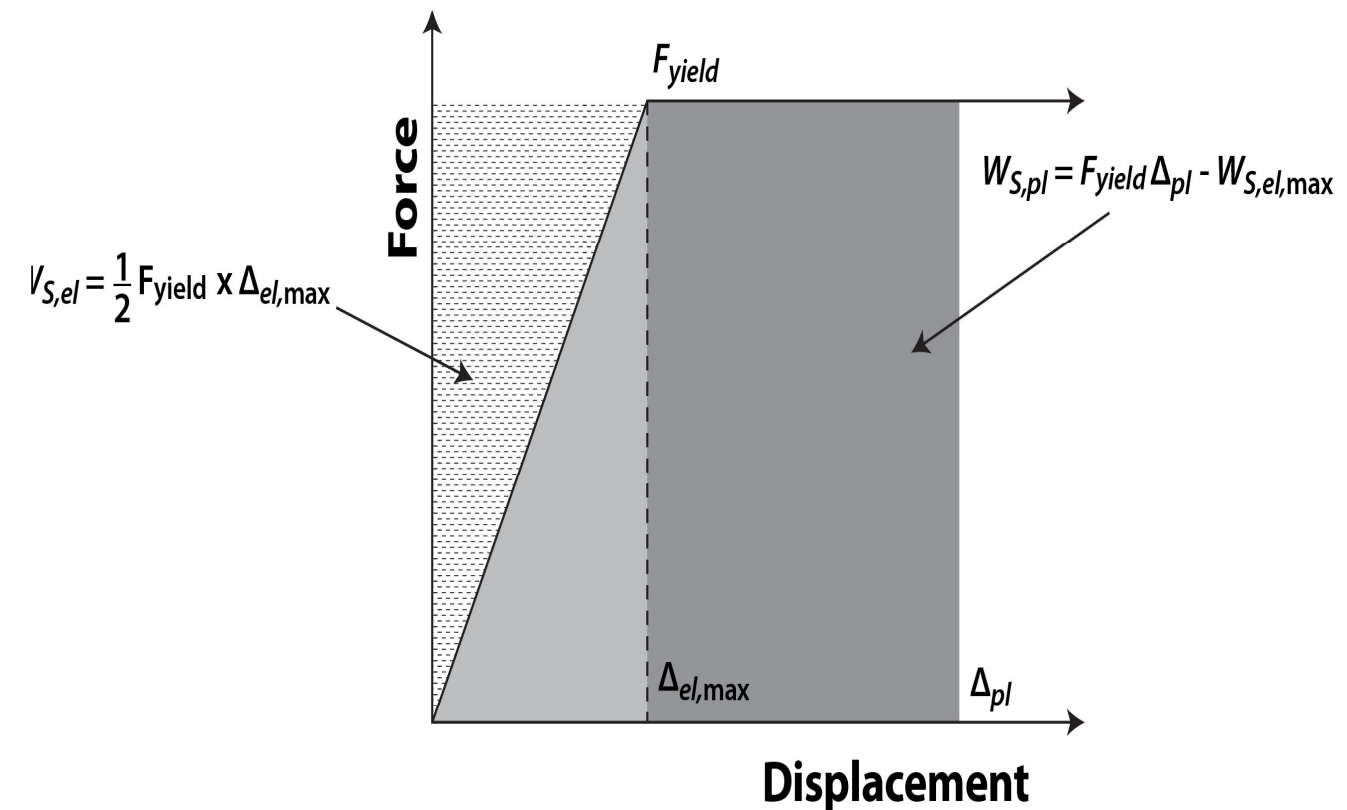
Blast Design – Strain Energy

Linear Elastic Behavior



$$\mu = 1.0$$

Linear Elastic-Plastic Behavior



$$\mu > 2.0$$

Blast Theory – Energy Absorption

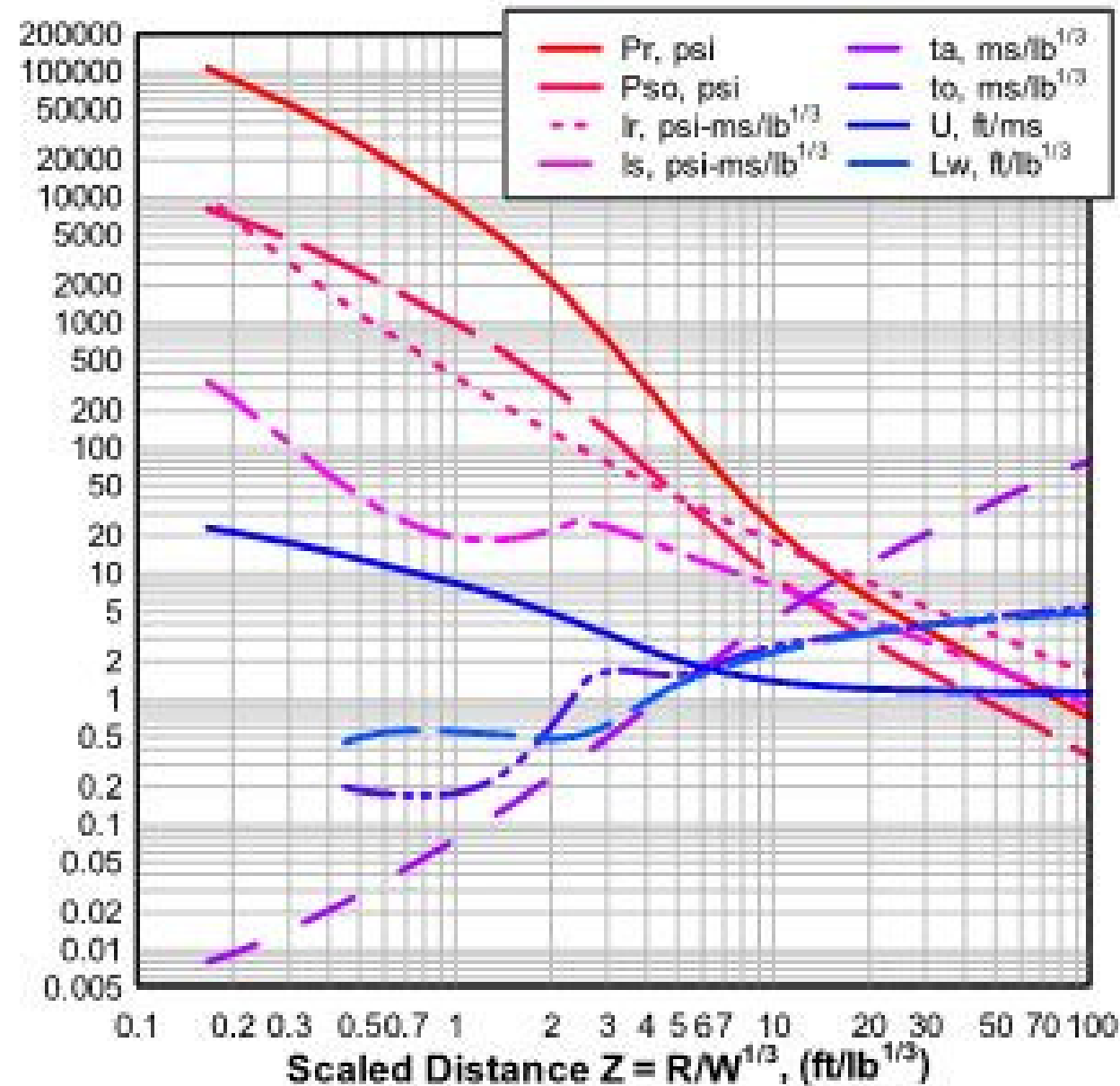


- Laminated Glass
 - 1st Level
 - 2 1/2"
 - Forced Entry Resistant
 - Ballistic Resistant
 - Blast Resistant
 - 2nd & 3rd Level
 - 2"
 - Blast Resistant

Blast Design Process

1. Explosion Hazard
2. Blast Loads
3. Trial Structural System
4. Dynamic Material Properties
5. Structural Analysis – Primary members
6. Structural Design – Secondary Members
7. Performance Criteria
8. Drawings & Details

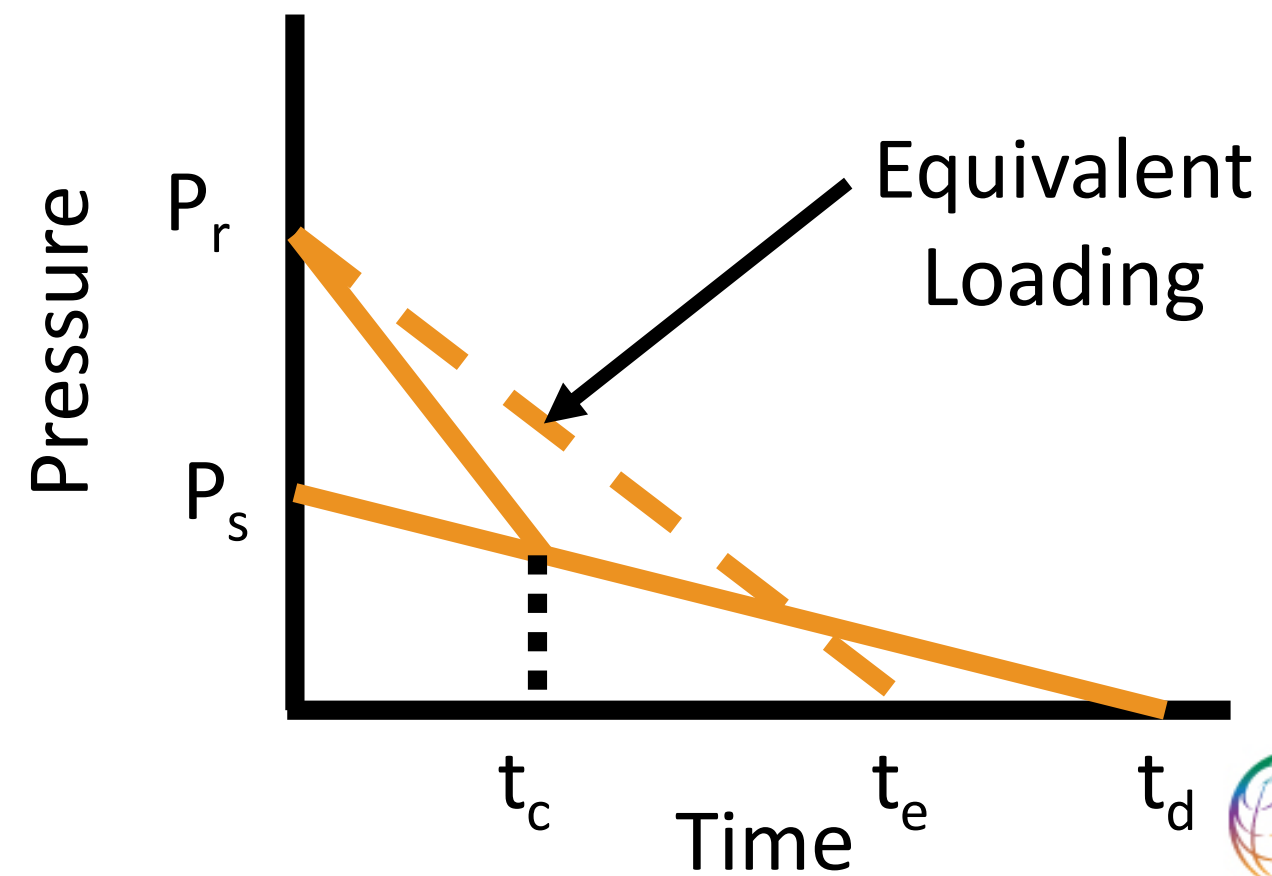
Blast Loads - Charts



$$\text{Scaled Distance } Z = R/W^{1/3}$$

R = Stand-Off Distance

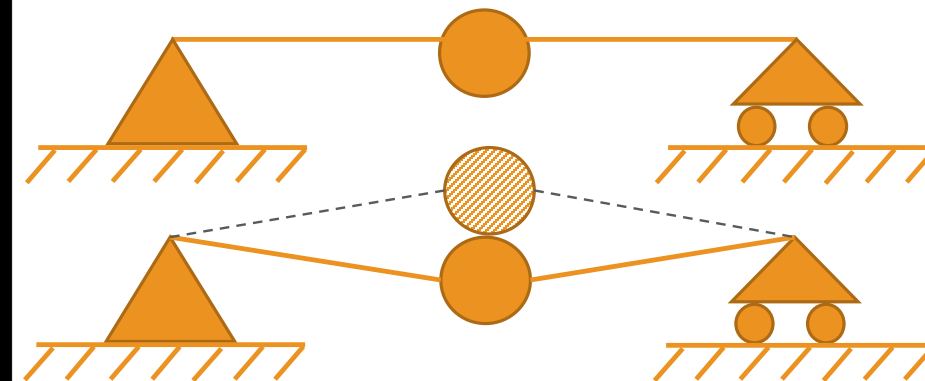
W = Equivalent TNT Charge Weight



Equivalent SDOF & MDOF Systems

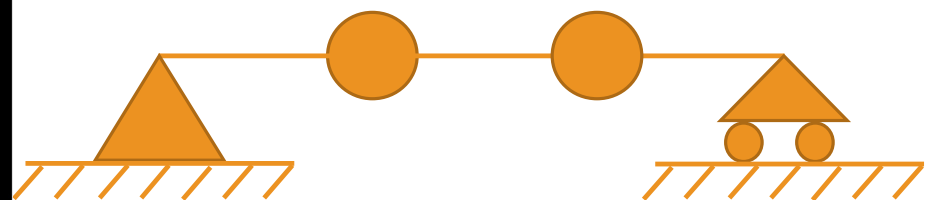
Multiple-DOF Oscillators

Dr. Dan Russell
Graduate Program in Acoustics
Pennsylvania State University
<http://www.acs.psu.edu/drussell>



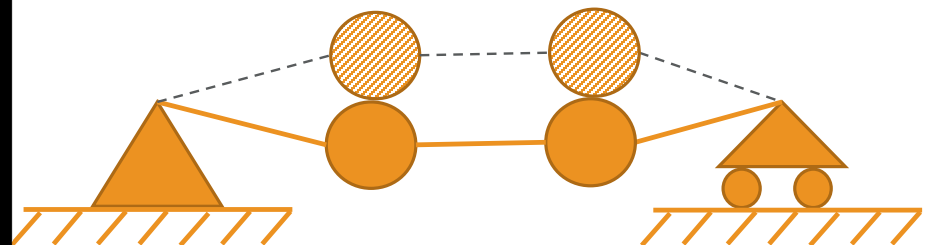
SDOF

1 Mode Shape
1 Natural Frequency

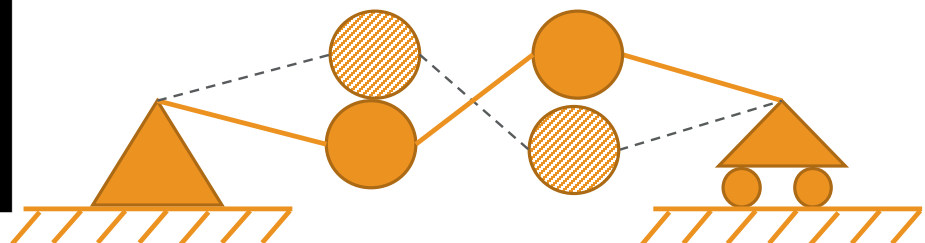


MDOF (2)

2 Mode Shape
2 Natural Frequencies

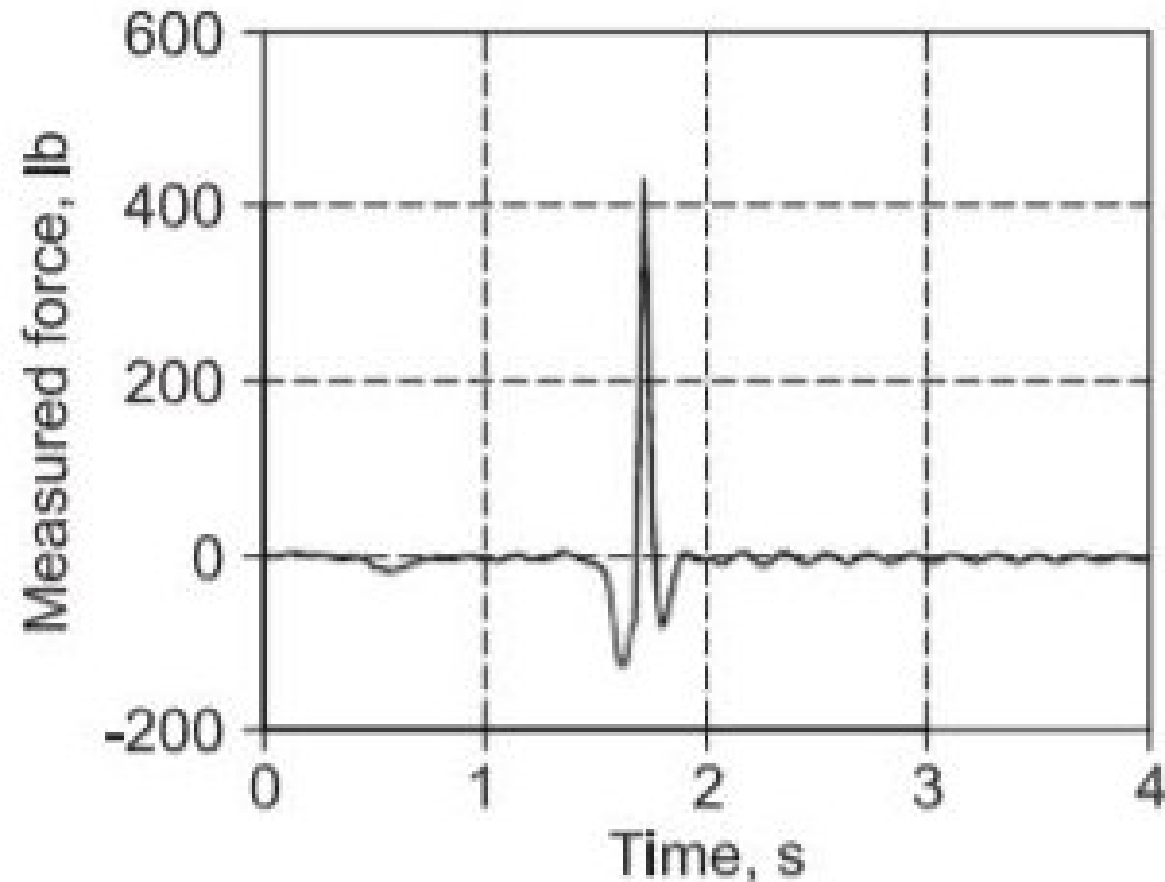


1st Mode Shape
1st Natural Frequency



2nd Mode Shape
2nd Natural Frequency

Dynamic Analysis (Static – Dynamic = Time)



(a) Heel-drop dynamic force waveform

Time \gg Natural Period = Static

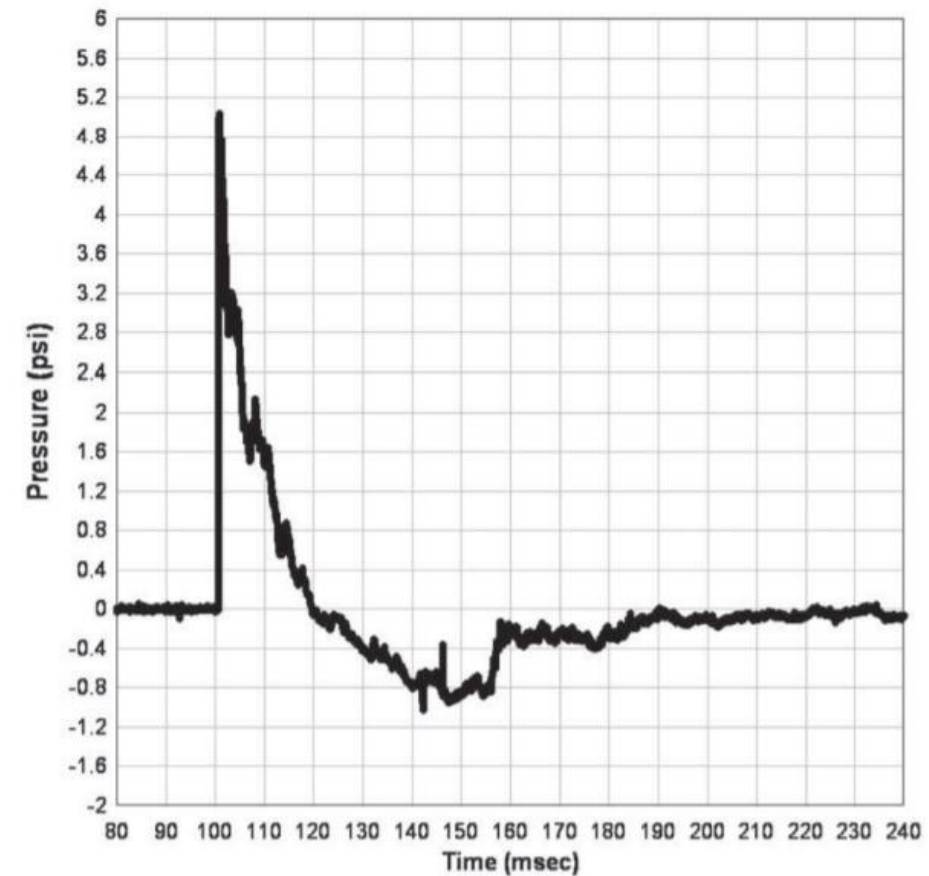
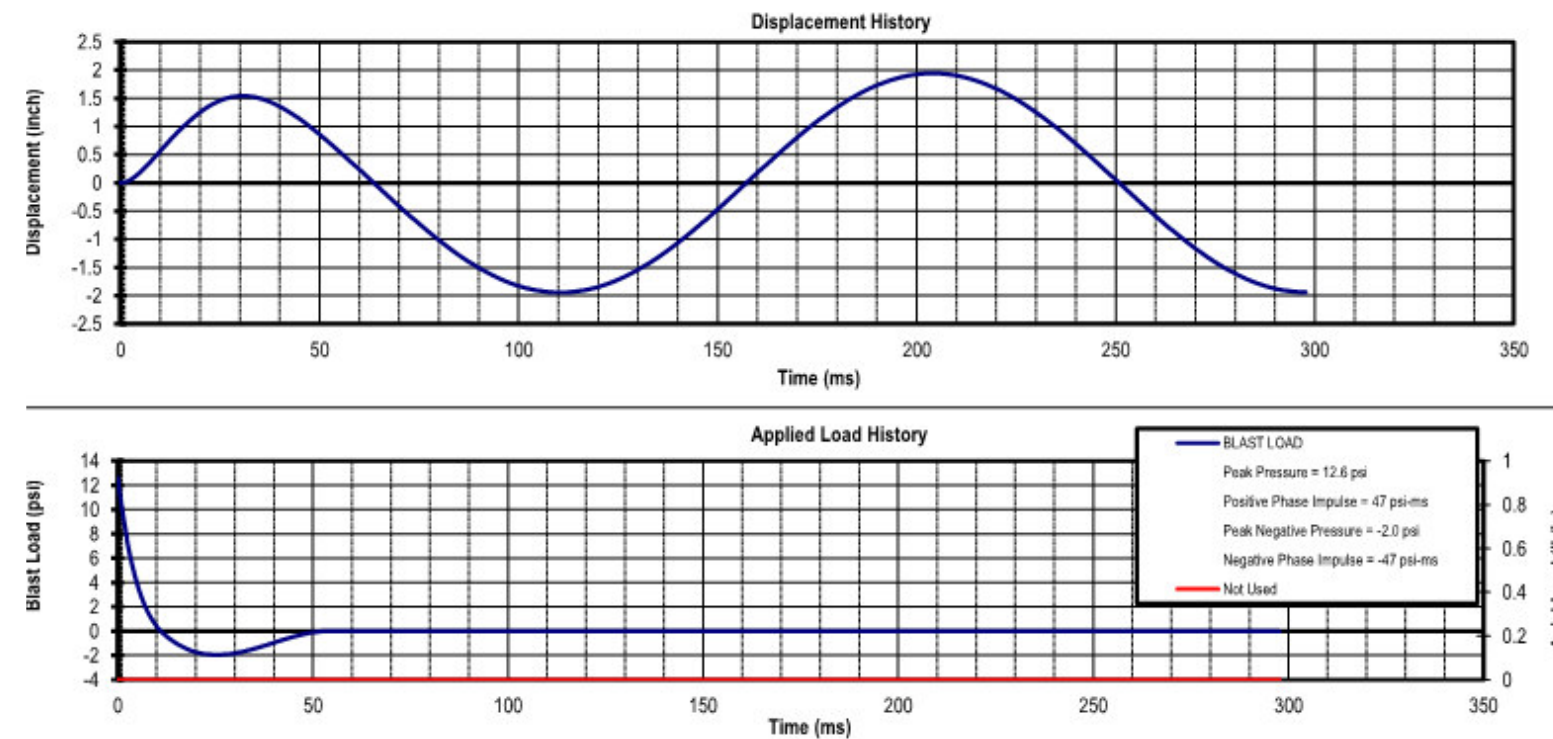


Fig. 1-1. Pressure gauge trace from high-energy explosive detonation.

Time \ll Natural Period = Dynamic

Analysis Methods

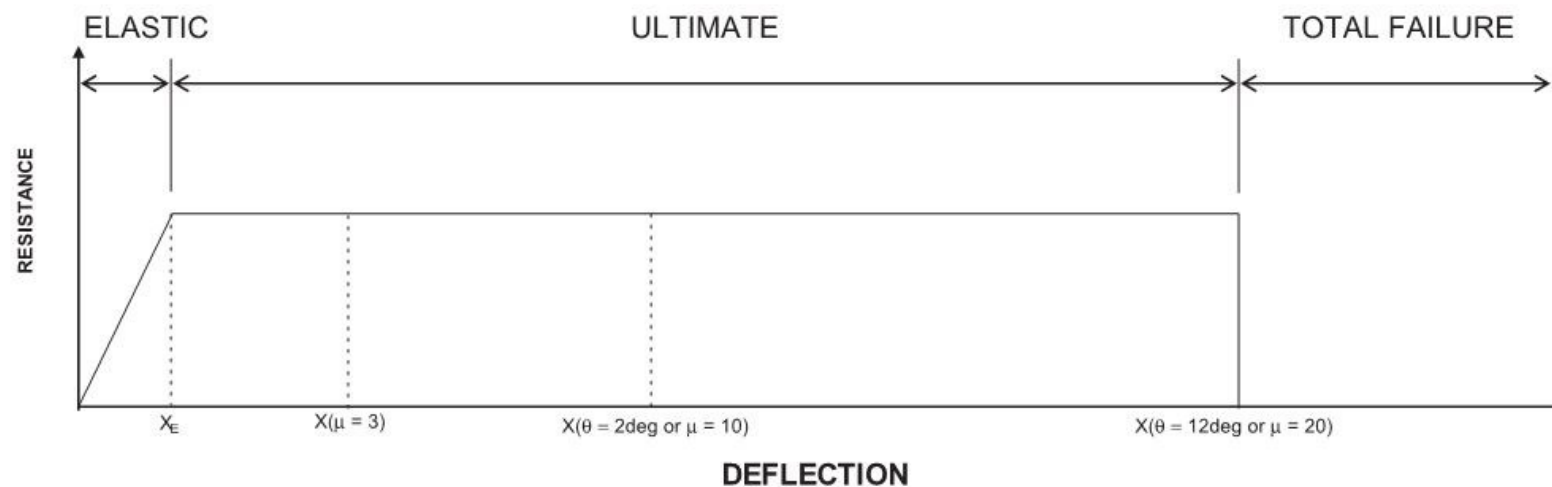
- Static Equivalent Elastic Analysis
 - Member Remains Elastic
 - DLF
 - Too Conservative
 - $1.0DL + .25LL + 1.0 B$
- Dynamic Finite Element Analysis
 - Non-Linear
 - Special Software
 - Too Time Consuming
 - Allowable Deformation



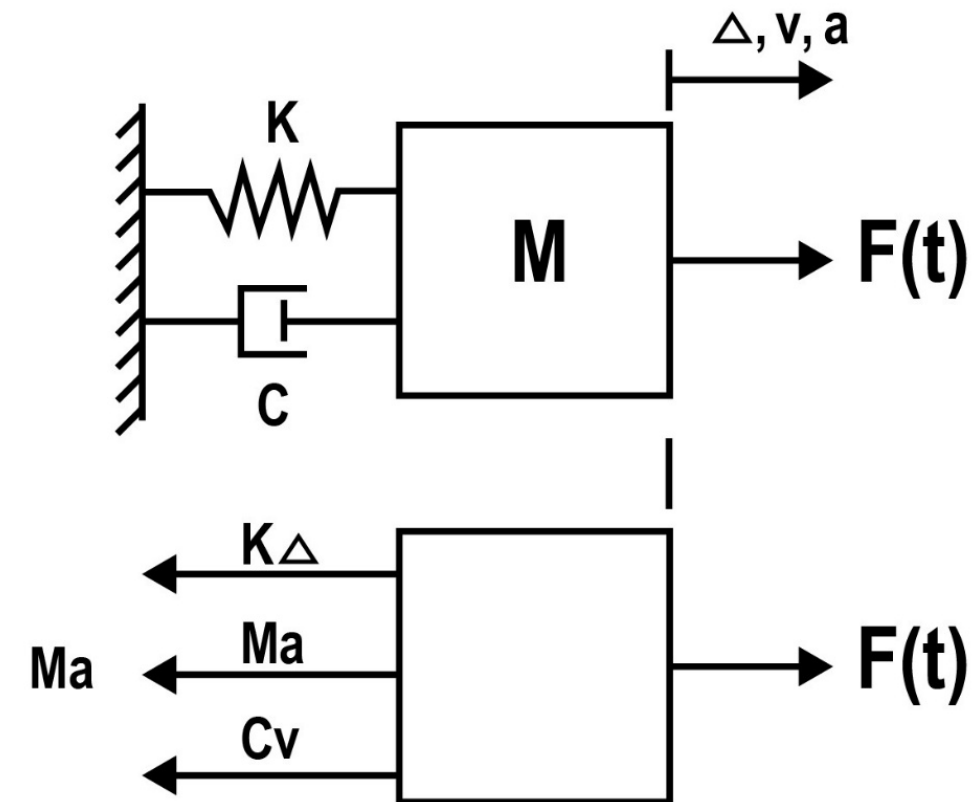
Analysis Methods - SDOF

- **Equivalent Single Degree of Freedom System (SDOF)**

- Assumes Flexural Member Response is Dominant Failure Mode
- Allows Both Elastic & Plastic Deformation (Non-Linear)
- Time-Step Dynamic Analysis
- Allowable Deformation at Mid-Span



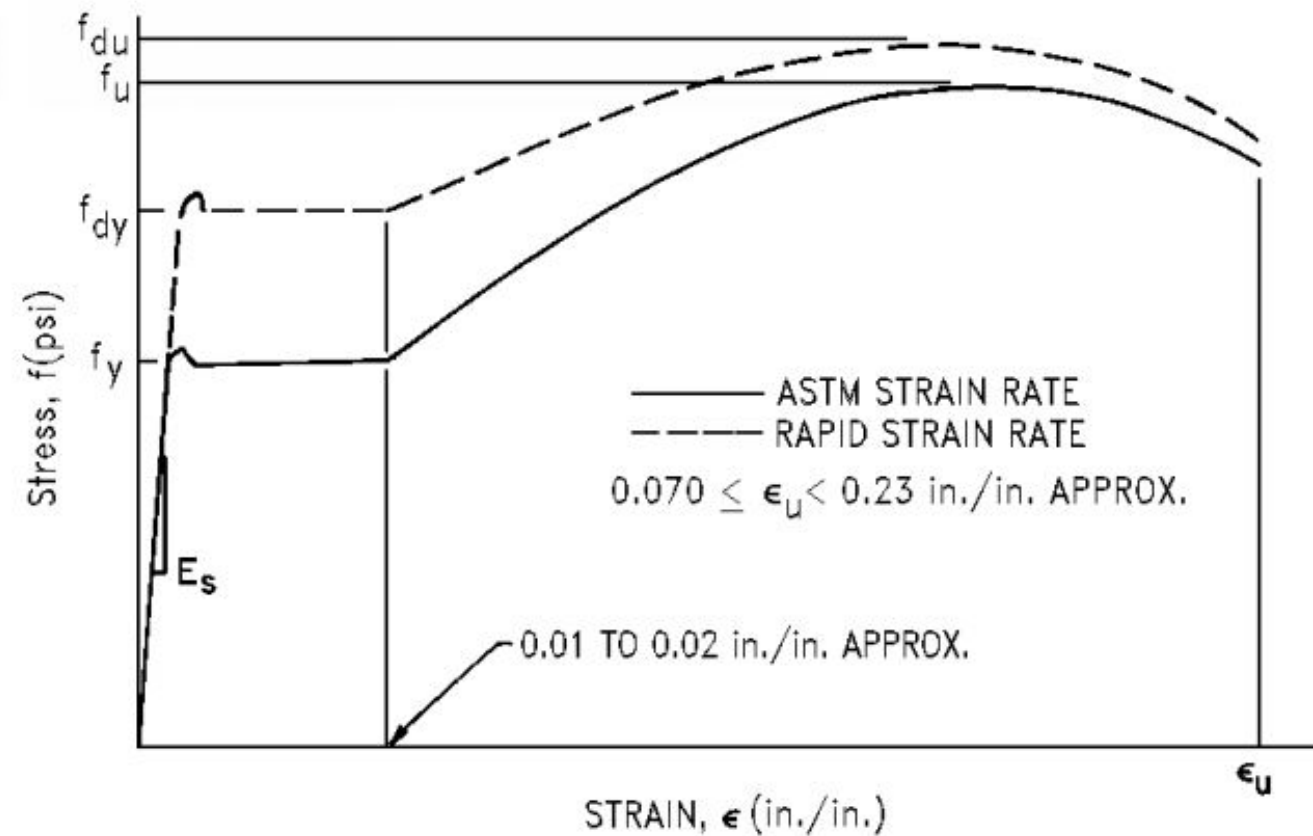
Equivalent SDOF System



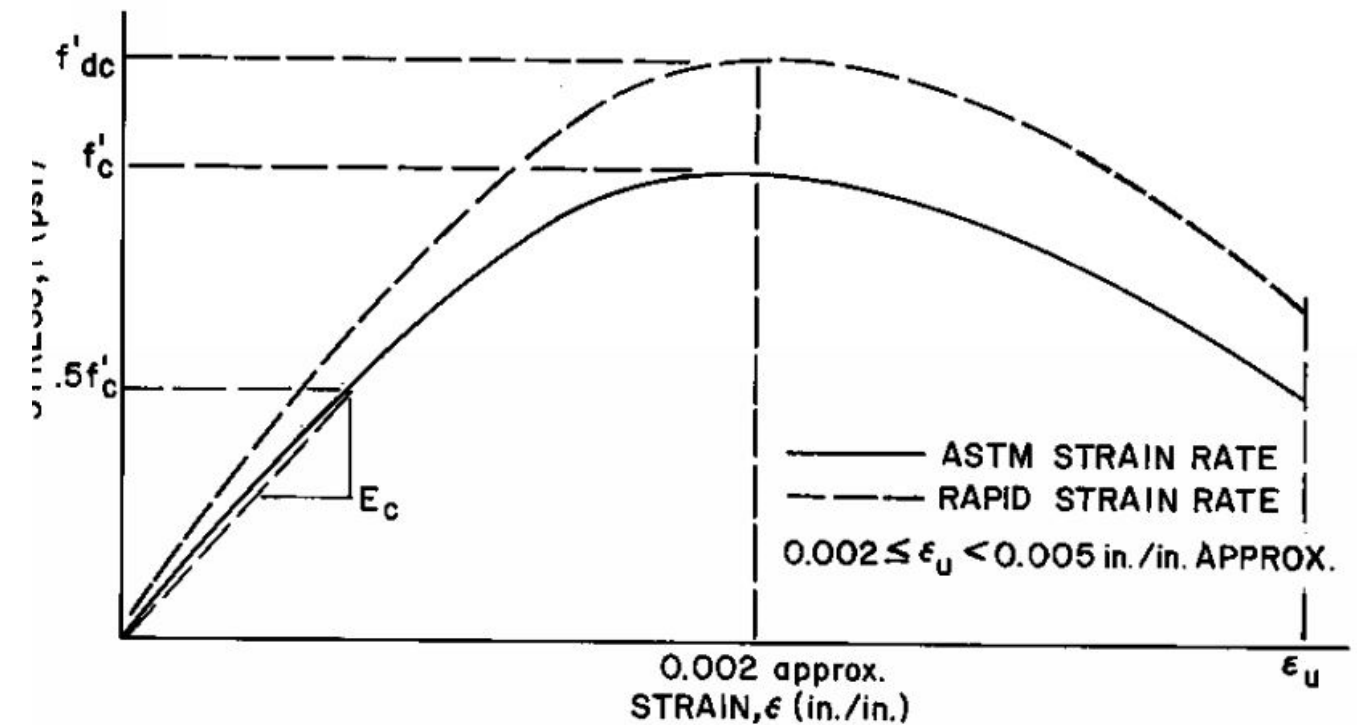
Equation of Motion

$$K_{LM} \cdot Ma(t) + C \cdot v(t) + K_\Delta(t) = F(t)$$

Dynamic Strength Increase



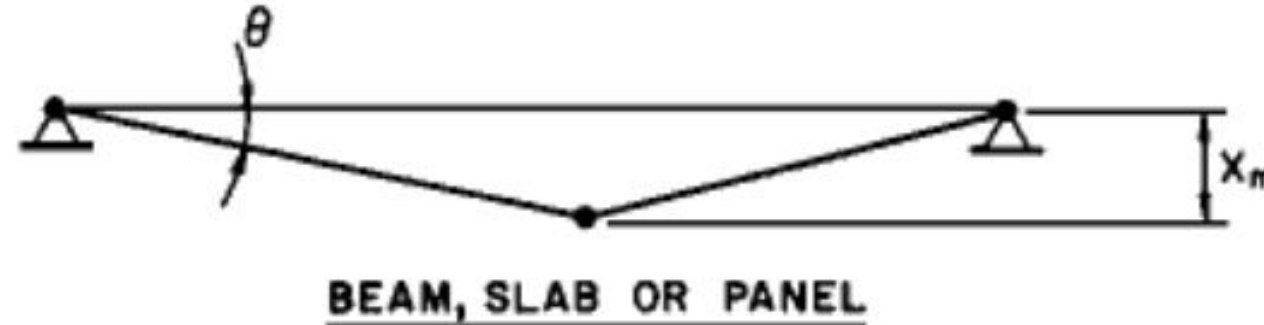
Stress-Strain Curve for Steel



(a) STRESS-STRAIN CURVE FOR CONCRETE

Stress-Strain Curve for
Concrete

Performance Criteria



Member		B1		B2		B3		B4	
		μ	θ	μ	θ	μ	θ	μ	θ
Flexure	Compact or seismic member	1	-	3	3°	12	10°	25	20°
	Non compact member	.7		.85		1.0		1.2	
	Plate ²	4	1°	8	2°	20	6°	40	12°
Combined Flexure & Compression	Compact or seismic member ²	1	-	3	3°	3	3°	3	3°
	Non compact member ³	.7		.85		.85		.85	
Compression ⁴		0.9		1.3		2		3	

SDOF – SBEDS - Input

Building: Sample Component: LG Wall Stud By: IEI Date: _____

SBEDS - 1: Metal Stud Wall

User Info: Fill in Yellow Cells, See Note Below for White Cells³

Wall Span, L: 14 ft
Stud Spacing, B: 1.33 ft
Select Boundary Condition, Response Type: Simple-Simple, Uniformly Loaded Flexural

Structural & Material Properties

Axis of Bending: Strong (X-X) Shape: 600S250-54
Stud Self-Weight, w: 2.28 lb/ft
Moment of Inertia, I: 3.76 in⁴
Section Modulus, S: 1.16 in³
Web Thickness, tw: 0.057 in
Depth, d: 6.00 in
Area, A: 0.67 in²
Web Punch-Outs: Standard Web Punch-Outs
Supported Weight: 40 psf
No Dynamic Axial Load Static Axial Load, P': lb/in Note: (P>=0)
Leave Blank for No Axial Load
Not Used (only for tension membrane response)
Type of Track for Wall (for tension membrane response): Cold-formed track
Steel Type: A653, Gr. 50 (steel cold-formed)
Yield Strength, fy: 50,000 psi
Ultimate Strength, fu: 65,000 psi
Elastic Modulus, E: 29000000 psi
Static Strength Increase Factor: 1.21
Dynamic Increase Factor: 1.1
Dynamic Yield Stress, fdy: 66,550 psi
Not Used (only for DSSWS response mode)
Calculated Properties
Stud Moment Capacity: 77,131 lb-in
Maximum Tension Membrane Force in Stud, T: 0

Click to Input Blast Parameters

Blast Load Type: _____
Charge Wt (W) & Standoff (R): _____
Gravity Displacement: _____
None (vertical component)
Pressure-Time Input: _____
Time (ms): _____ Pressure (psi): _____
N/A N/A

Dynamic Reaction Factors

	Shear Constant	Elastic	Plastic
F constant =	0.11	0.12	
R constant =	0.39	0.38	

Solution Control

Inbound Natural Period:	187.21	ms
Rebound Natural Period:	187.21	ms
Max Recommended Time Step:	0.10	ms
Time Step:	0.1	ms
% of Critical Damping:		%
Initial Velocity:		in/ms

Charge weight (W) and Standoff (R)

W (lb)	Explosive Type
50	TNT
W/TNT Equiv (lb)	R (ft)
50	50

Blast Load Phase

Positive and negative phase
Blast Load Orientation: Reflected without Clearing
Parameters for Reflected Loads: _____
Wall Height (ft): N/A
Wall Width (ft): N/A
Incidence Angle: 0

See notes under SB5
Load File: AXIAL (above) BLAST (below)
Axial Load Input File Not Selected

Response Criteria (See Note 6)

Connected top and bottom
LOP Type: LLOP/Secondary-NS
0 (deg) 18
N/A 2

Results Summary

Wmax	deg	Design Criteria:	LLOP/Secondary-NS
0.83	Rebound	Response meets input design criteria	
Xmax Inbound =	-1.94	at time =	204.00 msec
Xmax Rebound =	-1.94	at time =	110.40 msec
Rmax =	1.28	at time =	204.00 msec
Rmin =	-1.28	at time =	110.40 msec

Shortest Yield Line Distance to Determine B: 64.0 in

Equivalent Static Reactions*

Result Displacements Based on Ultimate Flexural Resistance of Metal Studs: W
Vy at Support A = 1.836 lb
Vy at Support B = 1.836 lb
Flexural Shear Capacity
Shear Capacity: Vc = 3.234 lb
Results for Shear Check: Shear is OK
Req'd Distance from Support with Web Stiffeners (2): N/A in
Not Used for Conventional Stud Design
(1) Based on larger of rebound and rebound ultimate flexural resistance, not including tension membrane.
(2) Based on support with maximum Vc - Use stiffener spacing <= stud depth

Error/Warning Messages

Notes:
¹ Used for clearing of reflected load
² Angle in degrees from normal
³ Entering data in white cells will OVERWRITE formulas and cause ERRONEOUS results!
To recover formulas, save your input data and reinitiate Component Type on Intro worksheet.
⁴ Shear controlled response ONLY occurs if the user sets the "Shear Flag" > 0. This response typically has very limited ductility - a maximum value of 1 is assumed in SBEDS. The user should clearly understand shear-controlled response when using the shear flag - see User's Guide.
⁵ Axial load per unit width on analyzed component from saved Dynamic Shear History file for supported component. Dynamic axial load includes static gravity load of supported horizontal member.
⁶ For Response Criteria: TM = tension membrane
⁷ See User's Guide for Response Criteria for DSSWS (Ductile Steel Stud Wall System). These criteria are based on construction that are displayed with Click Button on Response Type input form.
⁸ This is the maximum compression force in the plate from composite flexural response with stud for DSSWS. Provide connections of plate to stud to resist this design force with LRFD design as shown in SBEDS User's Guide for Metal Stud Component.

Building: Sample Component: LG Wall Stud

SBEDS

User Info: Fill in Yellow Cells, See Note Below for White Cells³

Wall Span, L: 14 ft
Stud Spacing, B: 1.33 ft
Select Boundary Condition, Response Type: Simple-Simple, Uniformly Loaded Flexural

Structural & Material Properties

Axis of Bending: Strong (X-X) Shape: 600S250-54
Stud Self-Weight, w: 2.28 lb/ft
Moment of Inertia, I: 3.76 in⁴
Section Modulus, S: 1.16 in³
Web Thickness, tw: 0.057 in
Depth, d: 6.00 in
Area, A: 0.67 in²
Web Punch-Outs: Standard Web Punch-Outs
Supported Weight: 40 psf
No Dynamic Axial Load Static Axial Load, P': lb/in Note: (P>=0)
Leave Blank for No Axial Load
Not Used (only for tension membrane response)
Type of Track for Wall (for tension membrane response): Cold-formed track
Steel Type: A653, Gr. 50 (steel cold-formed)
Yield Strength, fy: 50,000 psi
Ultimate Strength, fu: 65,000 psi
Elastic Modulus, E: 29000000 psi
Static Strength Increase Factor: 1.21
Dynamic Increase Factor: 1.1
Dynamic Yield Stress, fdy: 66,550 psi
Not Used (only for DSSWS response mode)
Calculated Properties
Stud Moment Capacity: 77,131 lb-in
Maximum Tension Membrane Force in Stud, T: 0

Define Span, Spacing and End Fixity

Define Section

Define Supported Weight

Define Material Properties



SDOF – SBEDS – FRP Retrofit

FRP Selection

FRP Selection

Select Fiber Type

Carbon fiber

E-glass fiber

Aramid fiber

Steel-Reinforced Polymer

Yield Strength 154000 psi

Elastic Modulus 14800000 psi

Thickness 0.007 in

Fiber Layers

Unloaded Side Loaded Side

Fractional Layers Parallel to L: N/A N/A

Fractional Layers Parallel to H: N/A N/A

Environmental Reduction Factor (C_E):

Done

Environmental Reduction Factors from ACI 440.2R-08

Exposure conditions	Fiber type	Environmental reduction factor C _E
Interior exposure	Carbon	0.95
	Glass	0.75
	Aramid	0.85
Exterior exposure (bridges, piers, and unenclosed parking garages)	Carbon	0.85
	Glass	0.65
	Aramid	0.75
Aggressive environment (chemical plants and wastewater treatment plants)	Carbon	0.85
	Glass	0.50
	Aramid	0.70

Select Fiber Type

Carbon fiber

Select Reinforcement

Fyfe SCH-7UP/Tyfo® S

Fyfe SCH-41 /Tyfo® S

HJ3 BlastSeal™ CF-250

QuakeWrap™ VU18C

VSL V-Wrap C200

User Defined

Thickness 0.007 in

Select Fiber Type

E-glass fiber

Select Reinforcement

Fyfe SEH-51/Tyfo® S

Hexcel Hex-3R Wrap 430™

Mbrace® EG900

QuakeWrap™ VU20G

User Defined

Select Fiber Type

Aramid fiber

Select Reinforcement

Fyfe SAH-41 /Tyfo® S

Fyfe SAH-41 /Tyfo® S

Kevlar®

User Defined

Elastic Modulus 5800000 psi

Thickness 0.05 in

Select Fiber Type

Steel-Reinforced Polymer

Select Reinforcement

3x2-20-12 Hardwire®

3x2-20-12 Hardwire®

User Defined

SDOF – SBEDS - Input

Building: Sample Component: LG Wall Stud By: ICI Date:

SBEDS v5.1: Metal Stud Wall

User Info: Fill in Yellow Cells, See Note Below for White Cells¹

Wall Span, L: 14 ft
Stud Spacing, B: 1.33 ft
Select Boundary Condition, Response Type: Simple-Simple, Uniformly Loaded Flexural

Structural & Material Properties

Axis of Bending: Strong (P-X) Shape: W10x250.54
Stud Self-Weight, w: 2.28 lb/ft
Moment of Inertia, I: 3.76 in⁴
Section Modulus, S: 1.16 in³
Web Thickness, tw: 0.057 in
Depth, d: 6.00 in
Area, A: 0.87 in²
Web Punch-Outs: Standard Web Punch-Outs
Supported Weight: 40 psf
No Dynamic Axial Load Static Axial Load, P: 0 lb/in Note: (P>0) in
Leave Blank for No Axial Load

Not Used (only for tension membrane response)
Type of Track for Wall (for tension membrane response): Cold formed track
Steel Type: A653, or 50 (steel cold-formed)
Yield Strength, fy: 50,000 psi
Ultimate Strength, fu: 65,000 psi
Elastic Modulus, E: 29,000,000 psi
Static Strength Increase Factor: 1.21
Dynamic Increase Factor: 1.1
Dynamic Yield Stress, fyD: 66,550 psi
Not Used (only for DSSWS response mode)

Calculated Properties

Stud Moment Capacity: 77,131 lb-in
Maximum Tension Membrane Force in Stud, T: 0

Click to Input Blast Parameters

Charge Weight (W) and Standoff (R)
Gravity Displacement
Pressure-Time Input
Time (ms) Pressure (psi)
N/A N/A

Dynamic Reaction Factors

Blast Load Type
Charge Wt (W) & Standoff (R)
Shear Constant Elastic Plastic
F constant = 0.11 0.12
R constant = 0.39 0.38

Solution Control

Inbound Natural Period: 187.21 ms
Rebound Natural Period: 187.21 ms
Max Recommended Time Step: 0.10 ms
Time Step: 0.1 ms
% of Critical Damping: %
Initial Velocity: in/ms

Load Properties

Property Inbound Rebound Units
Mass, M 749.7 749.7 psi-ms/in
Load-Mass Factors, K_{LM}
K_{LM1} 0.78 0.78
K_{LM2} 0.78 0.78
K_{LM3} 0.66 0.66
K_{LM4} 0.66 0.66
K_{LM5} 0.66 0.66
Stiffness, K
K₁ 0.66 0.66 psil/in
K₂ 0.66 0.66 psil/in
K₃ 0.00 0.00 psil/in
K₄ 0.00 0.00 psil/in
K₅ 0.00 0.00 psil/in
Resistance, R
R₁ 1.37 -1.37 psi
R₂ 1.37 -1.37 psi
R₃ 1.37 -1.37 psi
R₄ 1.37 -1.37 psi
Yield Displacement, x
x1 2.08 -2.08 in
x2 2.08 -2.08 in
x3 2.08 -2.08 in
x4 2.08 -2.08 in
Equiv Yield Defl., X_E 2.08 -2.08 in

Response Criteria (See Note 6)

Connected top and bottom
LOP/Type LLOP/Secondary-NS
θ (deg) μ
N/A 2

Results Summary

θ_{max} = -1.32 deg Design Criteria: LLOP/Secondary-NS
u = 0.93 Rebound Response meets input design criteria
X_{max} Inbound = 1.94 in at time = 204.0 msec
X_{max} Rebound = -1.94 in at time = 110.4 msec
R_{max} = 1.28 psi at time = 204.0 msec
R_{min} = -1.28 psi at time = 110.4 msec
Shortest Yield Line Distance to Determine θ: 84.0 in

Equivalent Static Reactions²

Peak Reactions Based on Ultimate Flexural Resistance of Metal Studs (V_u)
Vu at Support A = 1.836 lb
Vu at Support B = 1.836 lb
Flexural Shear Capacity
Shear Capacity, V_s = 3.234 lb
Results for Shear Check: Shear is OK
Right Distance from Support with Web Stiffeners (2) N/A in
Not Used for Conventional Stud Design

(1) Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.
(2) Based on support with maximum V_u - Use stiffener spacing <= stud depth

Error/Warning Messages

Notes

¹ Used for clearing of reflected load
² Angle in degrees from normal
³ Entering data in white cells will OVERWRITE formulas and cause ERRONEOUS results!
To recover formulas, save your input data and reinitiate Component Type on Intro worksheet.
⁴ Shear controlled response ONLY occurs if the user sets the "Shear Flag" > 0. This response typically has very limited ductility - a maximum value of 1 is assumed in SBEDS. The user should clearly understand shear-controlled response when using the shear flag - see User's Guide.
⁵ Axial load per unit width on analyzed component from saved Dynamic Shear History file for supported component. Dynamic axial load includes static gravity load of supported horizontal member.
⁶ For Response Criteria: TM = tension membrane
⁷ See User's Guide for Response Criteria for DSSWS (Ductile Steel Stud Wall System). These criteria are based on construction that are displayed with Click Button on Response Type input form.
⁸ This is the maximum compression force in the plate from composite flexural response with stud for DSSWS. Provide connections of plate to stud to resist this design force with LRFD design as shown in SBEDS User's Guide for Metal Stud Component.

ent: LG Wall Stud By: ICI

SBEDS v5.1: Metal Stud Wall

Click to Input Blast Parameters

Blast Load Type
Charge Wt (W) & Standoff (R)
Gravity Displacement
None (vertical component)
Pressure-Time Input
Time (ms) Pressure (psi)
N/A N/A

Charge Weight (W) and Standoff (R)

W (lb)	Explosive Type
50	TNT
W(TNT Equiv)(lb)	R (ft)
50	50

Blast Load Phase
Positive and negative phase
Blast Load Orientation
Reflected without Clearing
Parameters for Reflected Loads

Wall Height (ft) ¹	N/A
Wall Width (ft) ¹	N/A
Incidence Angle ²	0

See notes under B56

Load Files-AXIAL (above), BLAST (below)
AxialLoad Input File Not Selected
N/A
Response Criteria (See Note 6)
Connected top and bottom
LOP/Type LLOP/Secondary-NS
θ (deg) μ
N/A 2

See All COE Response Criteria for AT/FP (DSSWS Criteria not Included)

Define **Blast Parameters**

(Charge weight and standoff or Time History or multiple charge weights or standoffs)
Define Blast Phase and Blast Orientation

Reflected pressures with and without clearing or side-on pressure

Incidence Angle

Define Performance Criteria



SDOF – SBEDS - Input

Building: Sample Component: LG Wall Stud By: SBEDS v5.1: Metal Stud Wall

User Info: Fill in Yellow Cells, See Note Below for White Cells¹

Wall Span, L: 14 ft
Stud Spacing, B: 1.33 ft
Select Boundary Condition, Response Type: Simple-Simple, Uniformly Loaded Flexural

Structural & Material Properties

Axial Load: 40 psf
Static Axial Load, P: 0 lb/in Note: (P>0)
Not Used (only for tension membrane response)
Type of Track for Wall (for tension membrane response): Cold-Formed Steel
Steel Type: 46SS, or 50 (steel cold-formed)
Yield Strength, f_y : 50,000 psi
Ultimate Strength, f_u : 65,000 psi
Elastic Modulus, E: 29,000,000 psi
Static Strength Increase Factor: 1.21
Dynamic Increase Factor: 1.1
Dynamic Yield Stress, f_{dy} : 66,550 psi
Not Used (only for DSSWS response mode)

Calculated Properties

Stud Moment Capacity: 77,131 lb-in
Maximum Tension Membrane Force in Stud, T: 0

Click to Input Blast Parameters

Blast Load Type: Charge Wt (W) & Standoff (R)
Gravity Displacement: None (vertical component)
Pressure-Time Input: Time (ms): Pressure (psi):
N/A N/A

Dynamic Reaction Factors

Shear Constant: 0.11 Elastic: 0.12 Plastic: 0.38
F constant = 0.11
R constant = 0.39

Solution Control

Inbound Natural Period: 187.21 ms
Rebound Natural Period: 187.21 ms
Max Recommended Time Step: 0.10 ms
Time Step: 0.1 ms
% of Critical Damping: 0.1 %
Initial Velocity: in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	749.7	749.7	psi-ms ² /in
Load-Mass Factors, K_{LM}			
K_{LM1}	0.78	0.78	
K_{LM2}	0.78	0.78	
K_{LM3}	0.66	0.66	
K_{LM4}	0.66	0.66	
K_{LM5}	0.66	0.66	
Stiffness, K			
K_1	0.66	0.66	psi/in
K_2	0.66	0.66	psi/in
K_3	0.00	0.00	psi/in
K_4	0.00	0.00	psi/in
K_5	0.00	0.00	psi/in
Resistance, R			
R_1	1.37	-1.37	psi
R_2	1.37	-1.37	psi
R_3	1.37	-1.37	psi
R_4	1.37	-1.37	psi
Yield Displacement, x			
x1	2.08	-2.08	in
x2	2.08	-2.08	in
x3	2.08	-2.08	in
x4	2.08	-2.08	in
Equiv Yield Defl., X_E	2.08	-2.08	in

Results Summary

Design Criteria: LLCP/Secondary-NS
Response meets input design criteria
X_{max} Inbound = 1.94 in at time = 204.00 msec
X_{max} Rebound = -1.94 in at time = 110.40 msec
R_{max} = 1.28 psi at time = 204.00 msec
R_{min} = -1.28 psi at time = 110.40 msec
Shortest Yield Line Distance to Determine ϕ : 64.0 in

Equivalent Static Reactions

Point Reactions Based on Ultimate Shear Resistance of Metal Studs, V_u
Vu at Support A = 1.836 lb
Vu at Support B = 1.836 lb
Flexural Shear Capacity
Shear Capacity: V_s = 3.234 lb
Results for Shear Check: Shear is OK
Req'd Distance from Support with Web Stiffeners (Z): N/A in
Not Used for Conventional Stud Design

(1) Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.
(2) Based on support with maximum V_s - Use stiffener spacing < stud depth

Error/Warning Messages

Notes:
¹ Used for clearing of reflected load
² Angle in degrees from normal
³ Entering data in white cells will OVERWRITE formulas and cause ERRONEOUS results!
To recover formulas, save your input data and reinitiate Component Type on Intro worksheet.
⁴ Shear controlled response ONLY occurs if the user sets the "Shear Flag" > 0. This response typically has very limited ductility - a maximum value of 1 is assumed in SBEDS. The user should clearly understand shear-controlled response when using the shear flag - see User's Guide.
⁵ Axial load per unit width on analyzed component from saved Dynamic Shear History file for supported component. Dynamic axial load includes static gravity load of supported horizontal member.
⁶ For Response Criteria: TM = tension membrane
⁷ See User's Guide for Response Criteria for DSSWS (Ductile Steel Stud Wall System). These criteria are based on construction that are displayed with Click Button on Response Type input form.
⁸ This is the maximum compression force in the plate from composite flexural response with stud for DSSWS. Provide connections of plate to stud to resist this design force with LRFD design as shown in SBEDS User's Guide for Metal Stud Component.

Dynamic Reaction Factors			
Shear Constant	Elastic	Plastic	
F constant =	0.11	0.12	
R constant =	0.39	0.38	

Solution Control			
Inbound Natural Period:	187.21	ms	
Rebound Natural Period:	187.21	ms	
Max Recommended Time Step	0.10	ms	
Time Step:	0.1	ms	
% of Critical Damping:		%	
Initial Velocity:		in/ms	

SDOF Properties			
Property	Inbound	Rebound	Units
Mass, M	749.7	749.7	psi-ms ² /in
Load-Mass Factors, K_{LM}			
K_{LM1}	0.78	0.78	
K_{LM2}	0.78	0.78	
K_{LM3}	0.66	0.66	
K_{LM4}	0.66	0.66	
K_{LM5}	0.66	0.66	
Stiffness, K			
K_1	0.66	0.66	psi/in
K_2	0.66	0.66	psi/in
K_3	0.00	0.00	psi/in
K_4	0.00	0.00	psi/in
K_5	0.00	0.00	psi/in
Resistance, R			
R_1	1.37	-1.37	psi
R_2	1.37	-1.37	psi
R_3	1.37	-1.37	psi
R_4	1.37	-1.37	psi
Yield Displacement, x			
x1	2.08	-2.08	in
x2	2.08	-2.08	in
x3	2.08	-2.08	in
x4	2.08	-2.08	in
Equiv Yield Defl., X_E	2.08	-2.08	in

Define Time Step, Damping and Initial Velocity. Typically, damping and initial velocity are zero. For most applications 0.1 is the maximum recommended time step

Load Mass Factors are determined by the program based on the inputs and Resulting Resistance and Yield Displacements are calculated



SDOF – SBEDS - Output

Building: SampleComponent: LG Wall StudBy: IEIDate:

User Info: Fill in Yellow Cells, See Note Below for White Cells¹

Wall Span, L:14 ft

Stud Spacing, B:1.33 ft

Select Boundary Condition:

Simple-Single, Uniformly Loaded

Response Type:

Flexural

Structural & Material Properties

Axis of Bending: Strong (X-X)

Shape: I60X250-S4

Stud Self-Weight, w:2.28 lb/ft

Moment of Inertia, I:3.76 in⁴

Section Modulus, S:1.16 in³

Web Thickness, tw:0.057 in

Depth, d:6.00 in

Area, A:0.87 in²

Web Punch-Outs:

Standard Web Punch-Outs

Supported Weight:40 psf

No Dynamic Axial Load² Static Axial Load, P:lb/in Note: (P>0)

Leave Blank for No Axial Load

Not Used (only for tension membrane response)

Type of Task for Wall (for tension membrane response):Cold-formed track

Steel Type:

A572, Gr. 50 (steel with 50ksi)

Yield Strength, fy:50,000 psi

Ultimate Strength, fu:65,000 psi

Elastic Modulus, E:29000000 psi

Static Strength Increase Factor:1.21

Dynamic Increase Factor:1.1

Dynamic Yield Stress, fy:66,550 psi

Not Used (only for DSSWS response mode)

Calculated Properties

Stud Moment Capacity:77,131 lb-in

Maximum Tension Membrane Force in Stud, T:0

Click to Input Blast Parameters

Blast Load Type:

Charge With (M) & Standoff (R)

Gravity Displacement:

None (vertical component)

Pressure-Time Input

Time (ms):

Pressure (psi):

N/A

N/A

Dynamic Reaction Factors

Shear Constant:

Elastic:

Plastic:

F constant =:

0.11

0.12

R constant =:

0.30

0.38

Solution Control

Inbound Natural Period:

187.21

ms

Rebound Natural Period:

187.21

ms

Max Recommended Time Step:

0.10

ms

Time Step:

0.1

ms

% of Critical Damping:

%

Initial Velocity:

in/ms

SDOF Properties

Property:

Inbound:

Rebound:

Units:

Mass, M:

749.7

749.7

psi-ms²/in

Load-Mass Factors, K_{LU}:

K_{LU1}:

0.78

0.78

K_{LU2}:

0.78

0.78

K_{LU3}:

0.66

0.66

K_{LU4}:

0.66

0.66

K_{LU5}:

0.66

0.66

Stiffness, K:

psi/in

K₁:

0.66

0.66

psi/in

K₂:

0.00

0.00

psi/in

K₃:

0.00

0.00

psi/in

K₄:

0.00

0.00

psi/in

K₅:

0.00

0.00

psi/in

Resistance, R:

psi

R₁:

1.37

-1.37

psi

R₂:

1.37

-1.37

psi

R₃:

1.37

-1.37

psi

R₄:

1.37

-1.37

psi

Yield Displacement, x:

in

x1:

2.08

-2.08

in

x2:

2.08

-2.08

in

x3:

2.08

-2.08

in

x4:

2.08

-2.08

in

Equip Yield Defl., x_p:

2.08

-2.08

in

Charge Weight (W) and Standoff (R)

W (lb):

Explosive Type:

50

TNT

W/TNT Equiv (lb):

R (ft):

50

50

Blast Load Phase:

Positive and negative phase

Blast Load Orientation:

Reflected without Clearing

Parameters for Reflected Loads:

Wall Height (ft):

N/A

Wall Width (ft):

N/A

Incidence Angle³:

0

See notes under SDOF

Load File (AKA, below BLAST3D.mec):

Load and Input File Not Selected

N/A

Response Criteria (See Note 6)

Connected top and bottom

LOP/Type:

LLOP/Secondary-NS

θ (deg):

0

N/A

2

See All COE Response Criteria for AT/FP (DSSWS Criteria not included)

Error/Warning Messages

Notes:

¹ Used for clearing of reflected load

² Angle in degrees from normal

³ Entering data in white cells will OVERWRITE formulas and cause ERRONEOUS result!

To recover formulas, save your input data and reinitiate Component Type on Intro worksheet.

⁴ Shear controlled response ONLY occurs if the user sets the "Shear Flag" > 0. This response typically has very limited ductility - a maximum value of 1 is assumed in SBEDS. The user should clearly understand shear-controlled response when using the shear flag - see User's Guide.

⁵ Axial load per unit width on analyzed component from saved Dynamic Shear History file for supported component. Dynamic axial load includes static gravity load of supported horizontal member.

⁶ For Response Criteria: TM = tension membrane

⁷ See User's Guide for Response Criteria for DSSWS (Ductile Steel Stud Wall System). These criteria are based on construction that are displayed with Click Button on Response Type input form.

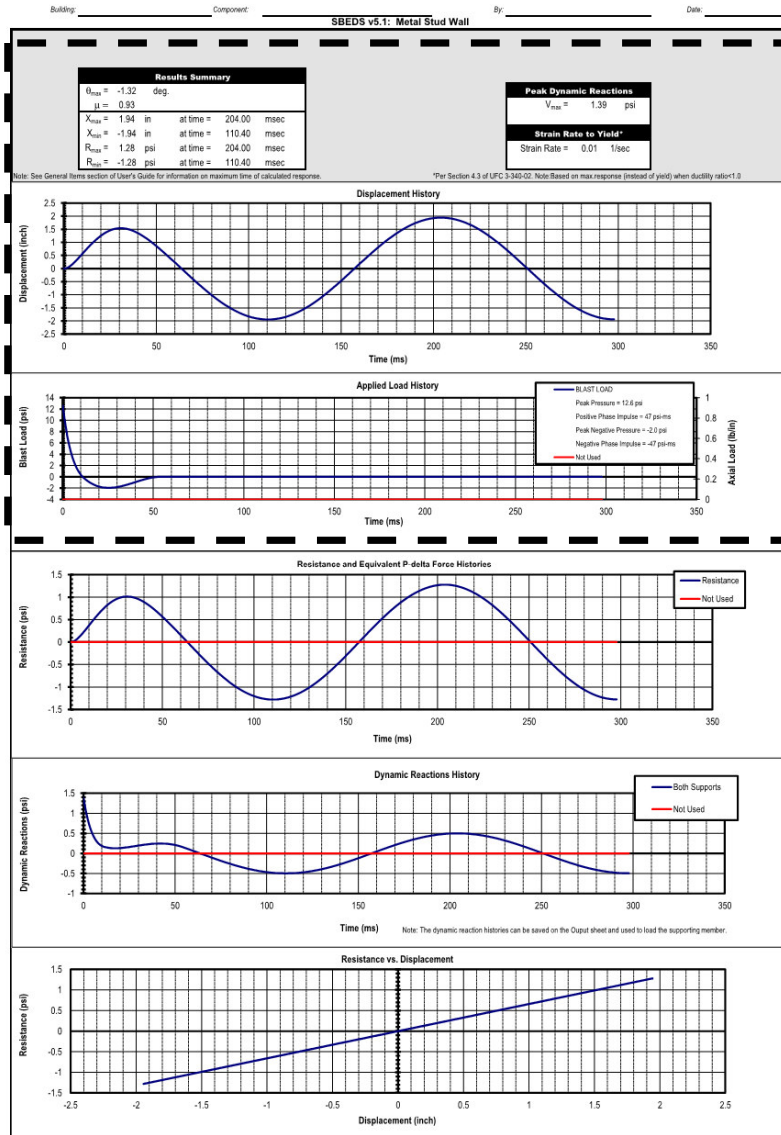
⁸ This is the maximum compression force in the plate from composite flexural response with stud for. DSSWS. Provide connections of plate to stud to resist this design force with LRFD design as shown in SBEDS User's Guide for Metal Stud Component.

Results Summary							
θ _{max} = -1.32 deg.	Design Criteria:	LLOP/Secondary-NS					
μ = 0.93 'Rebound	Response meets input design criteria						
X _{max} Inbound = 1.94 in	at time =	204.00	msec				
X _{min} Rebound = -1.94 in	at time =	110.40	msec				
R _{max} = 1.28 psi	at time =	204.00	msec				
R _{min} = -1.28 psi	at time =	110.40	msec				
Shortest Yield Line Distance to Determine θ:		84.0 in					
Equivalent Static Reactions*							
Peak Reactions Based on Ultimate Flexural Resistance of Metal Studs; Vu							
Vu at Support A =		1,836	lb				
Vu at Support B =		1,836	lb				
Flexural Shear Capacity							
Shear Capacity: V _s =		3,234	lb				
Results for Shear Check		Shear is OK					
Req'd Distance from Support with Web Stiffeners (2)		N/A	in				
Not Used for Conventional Stud Design							
(1) Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.							
(2) Based on support with maximum V _u - Use stiffener spacing <=stud depth							

Response Criterion are checked versus the analysis and maximum resistance and displacement are shown

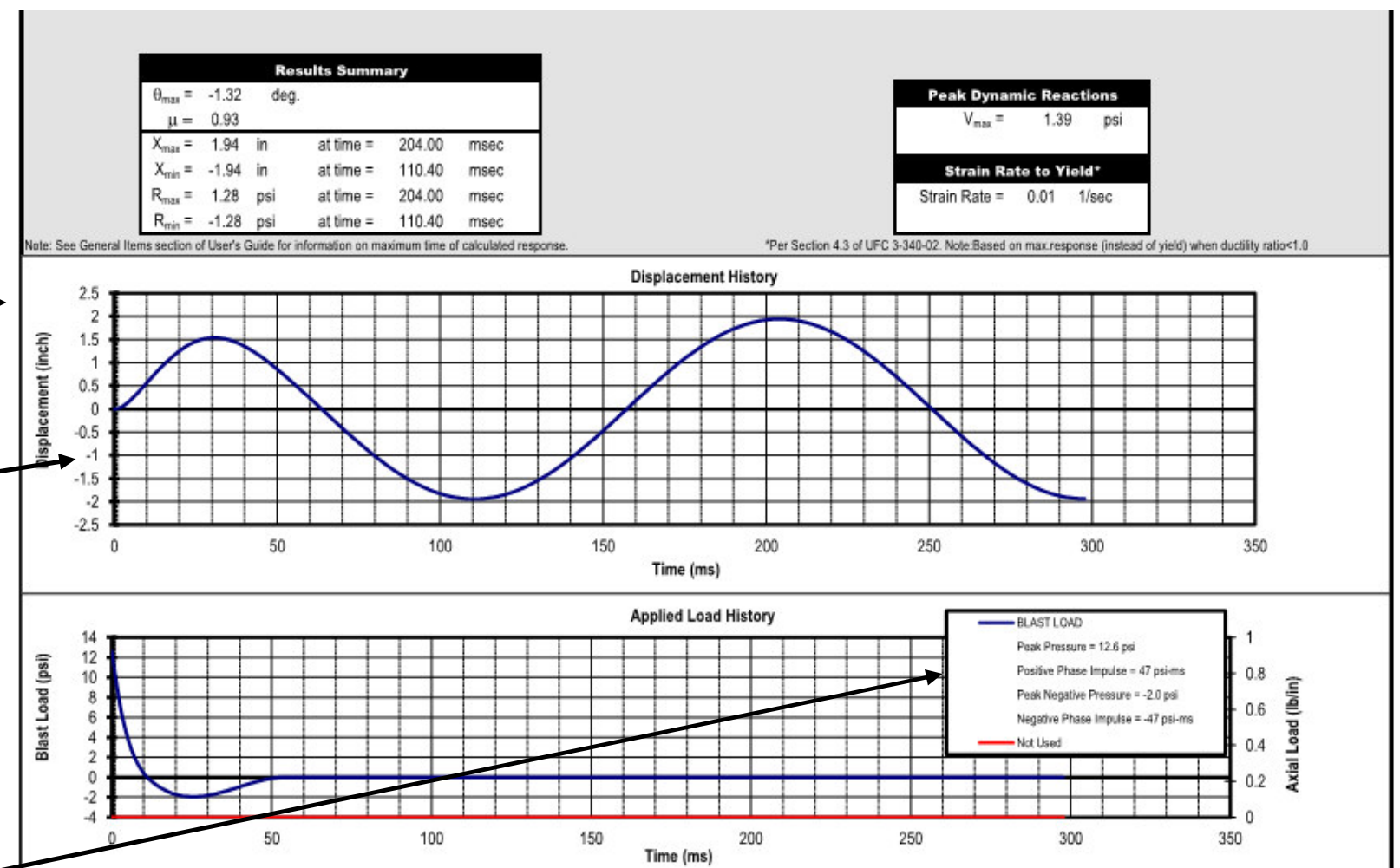
Equivalent Static Reactions are calculated and provided for connection design and shear checks a displayed

SDOF – SBEDS - Output

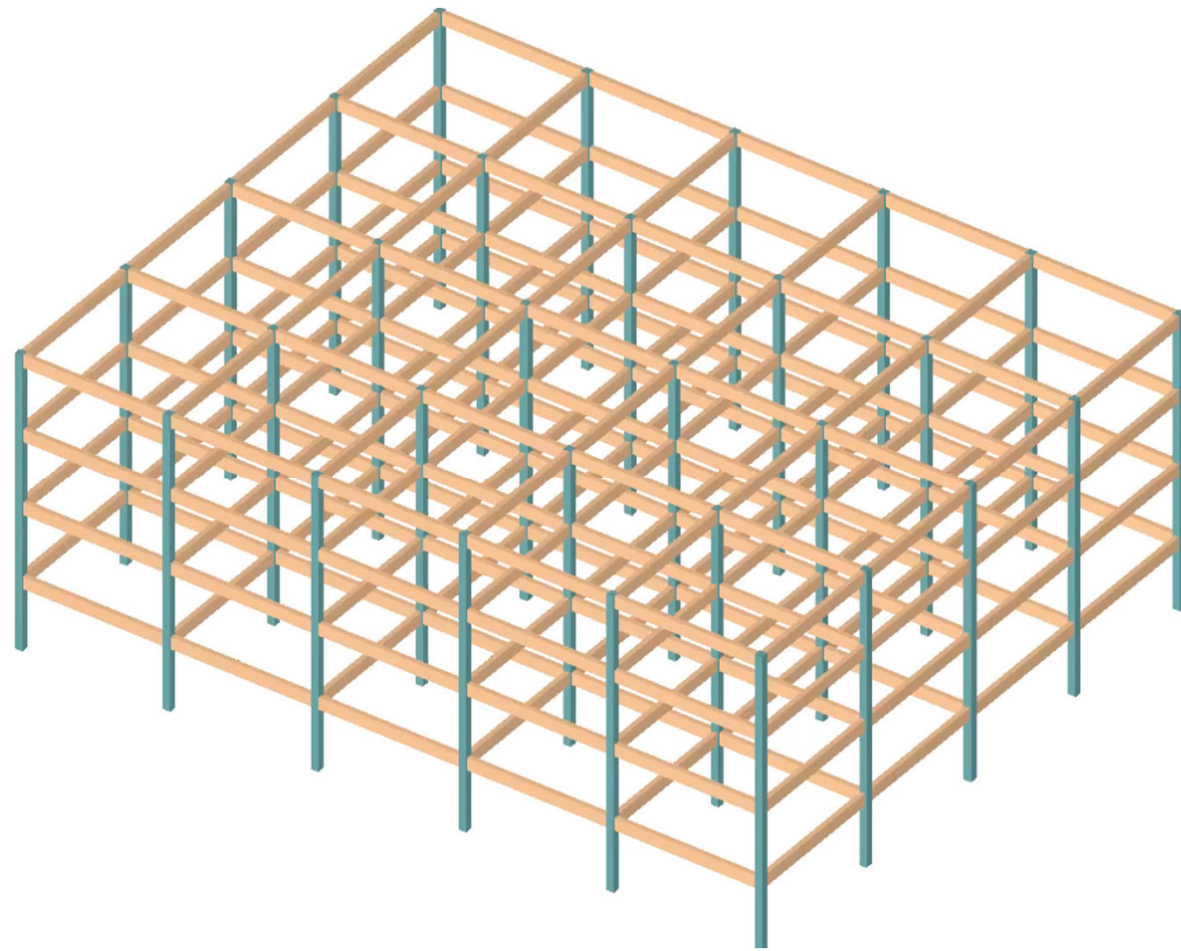


Graphical output displacement with respect to time is provided

Graphical output showing blast pressure with respect to time is provided along with peak pressures and impulses for positive and negative phases



Progressive Collapse



ASI Extreme Loading

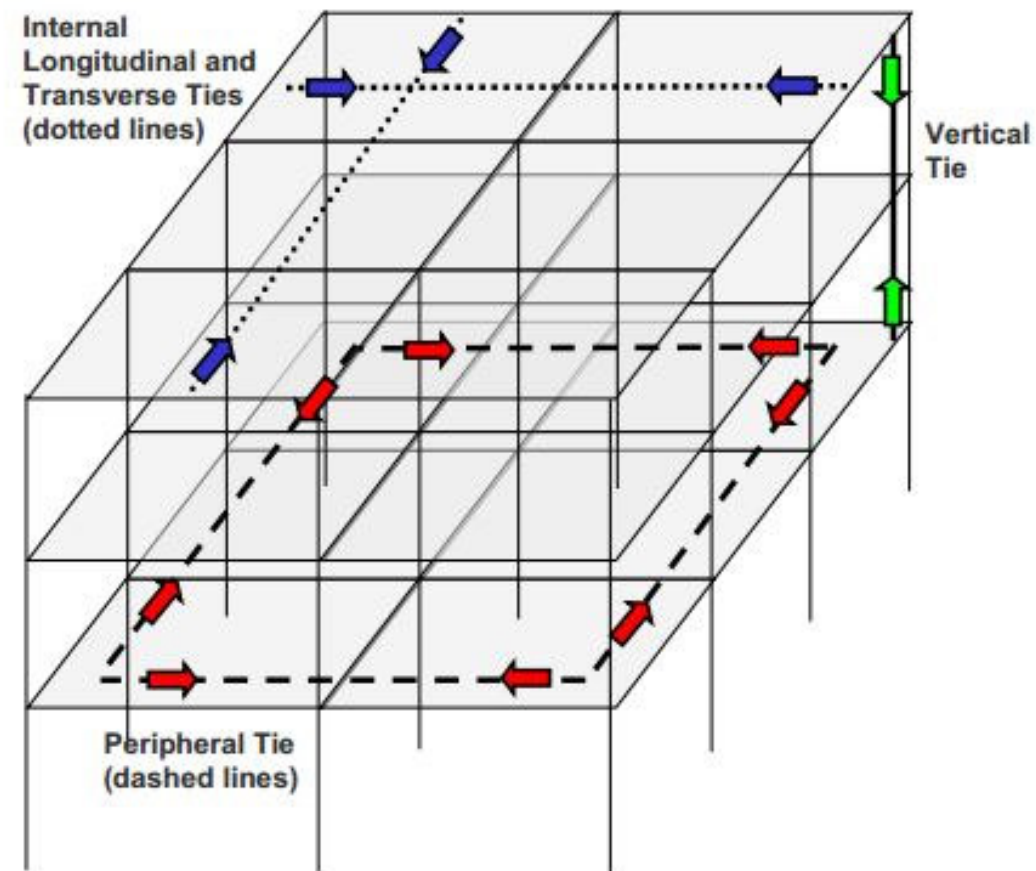
“The spread of an initial local failure from building element to building element, eventually resulting in the collapse of an entire structure or a disproportionately large part of it.”

Source: UFC 4-010-01

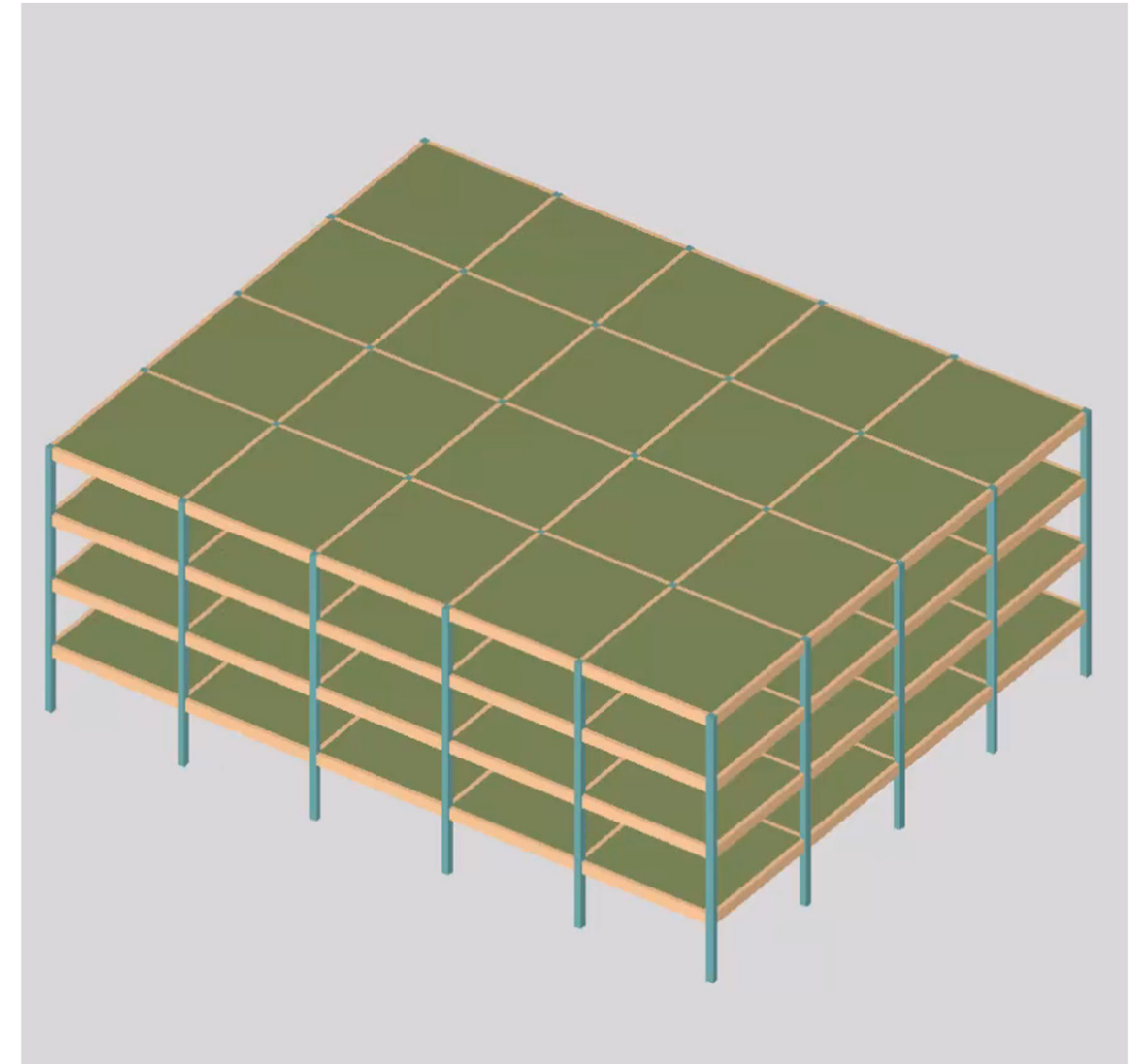
- Threat Independent
- Protect by:
 - Redundancy
 - Local Hardening

Progressive Collapse

Figure 3-1. Tie Forces in a Frame Structure



NOTE: 1. Peripheral, longitudinal and transverse ties are not required in floors above crawlspaces if public access control is provided.
2. Vertical ties are not required to extend to the foundation and shall be straight. /2/



Learning Objectives

- **Blast Theory**
- **Blast Analysis**
- **Blast Design**
- **Progressive Collapse**

Questions?

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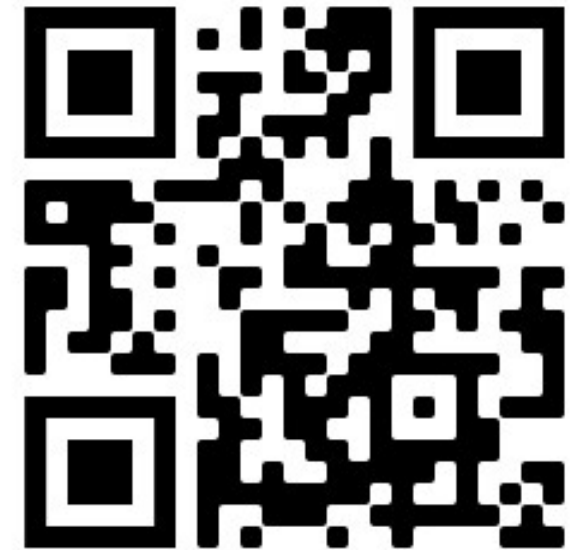
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