Structural Analysis & Design Software

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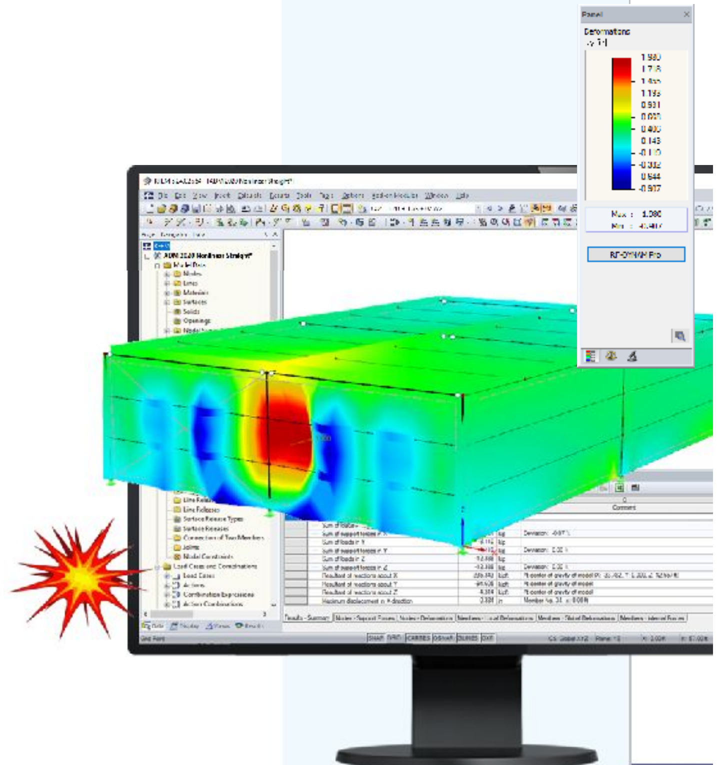
Webinar

Blast Time History Analysis in RFEM



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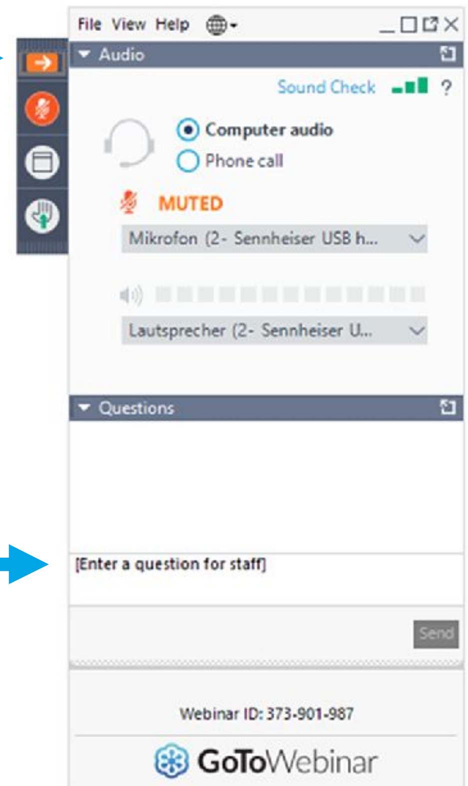

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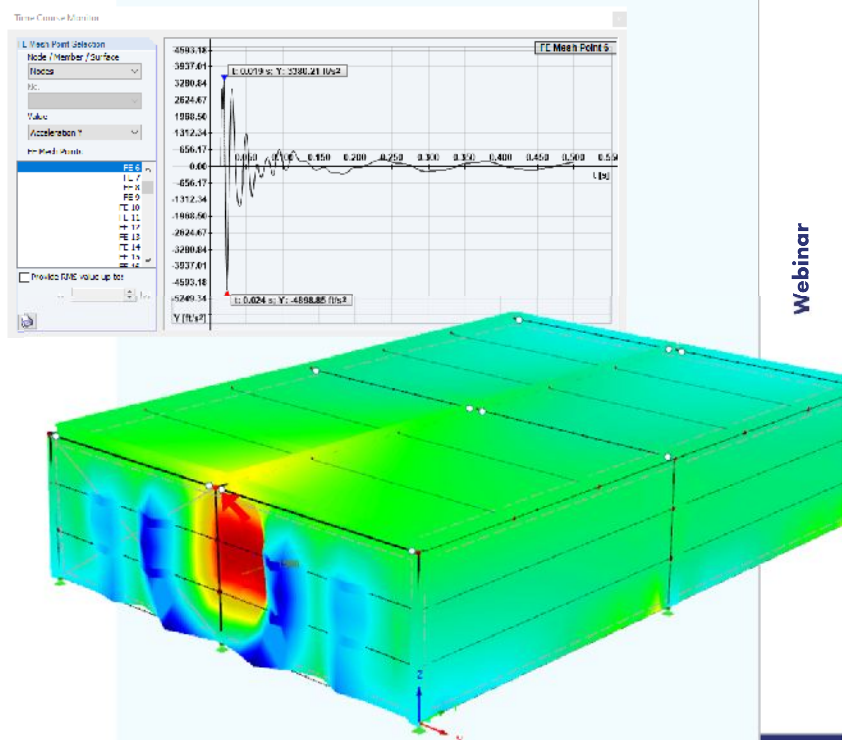
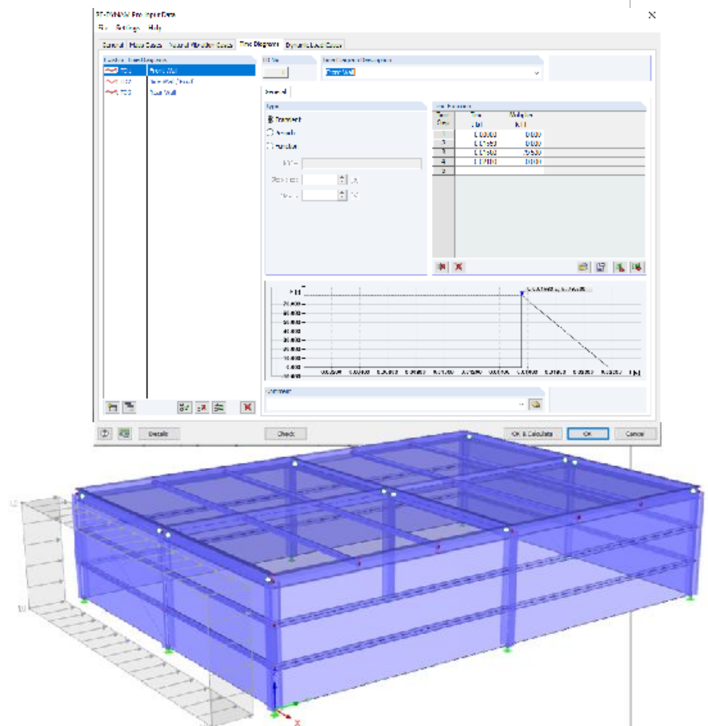


Blast Loading Basics

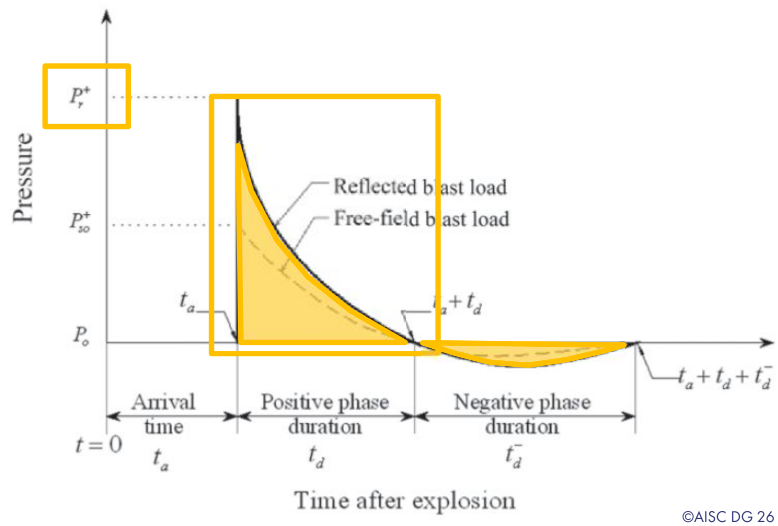
- **Design Resources**
  - AISC Design Guide 26 – Design of Blast Resistant Structures (AISC, 2013)
  - United Facilities Criteria 3-340-02, Structures to Resist the Effects of Accidental Explosions (DOD, 2008)
- **Factors influencing structural damage**
  - Structure materials, mass, stiffness
  - Explosive type and distance to structure
  - Blast orientation to structure and surrounding structures
- **Design Goals**
  - Avoid loss of life not necessarily avoid extensive structural damage
  - Steel often used as primary structural system for blast due to large inelastic deformation capability without loss of load carrying ability
  - Concrete has a higher mass and stiffness with higher temperature resistance



Blast Load Application

Idealized pressure-time history for blast load

- Peak overpressure (pressure above ambient atmospheric pressure) is an instantaneous pressure arriving at structure
- Positive phase duration is time period for pressure to return to ambient
- Positive impulse is total pressure-time energy applied during positive duration (area under curve)
- Negative phase duration, energy, impulse follows positive phase (pressure falls below atmospheric pressure)



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Blast Load Application (cont'd)

- **Free-field (side-on) blast load**
  - Blast load travels parallel to a surface
  - Sweep over the surface with no impeding objects
  - Subscript "so" used for side-on
- **Reflected blast load**
  - Blast load strikes an angled surface other than parallel
  - $P_r = C_r P_{so}$

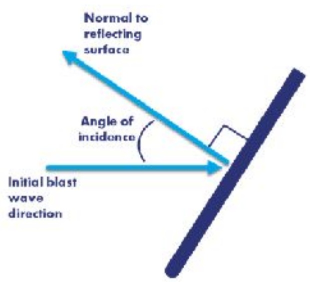
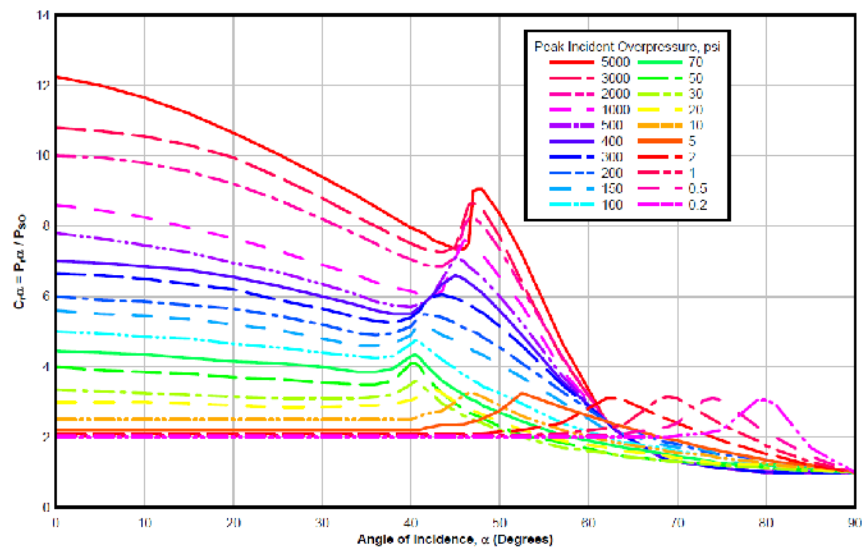


Figure 2-193 Reflected Pressure Coefficient versus Angle of Incidence



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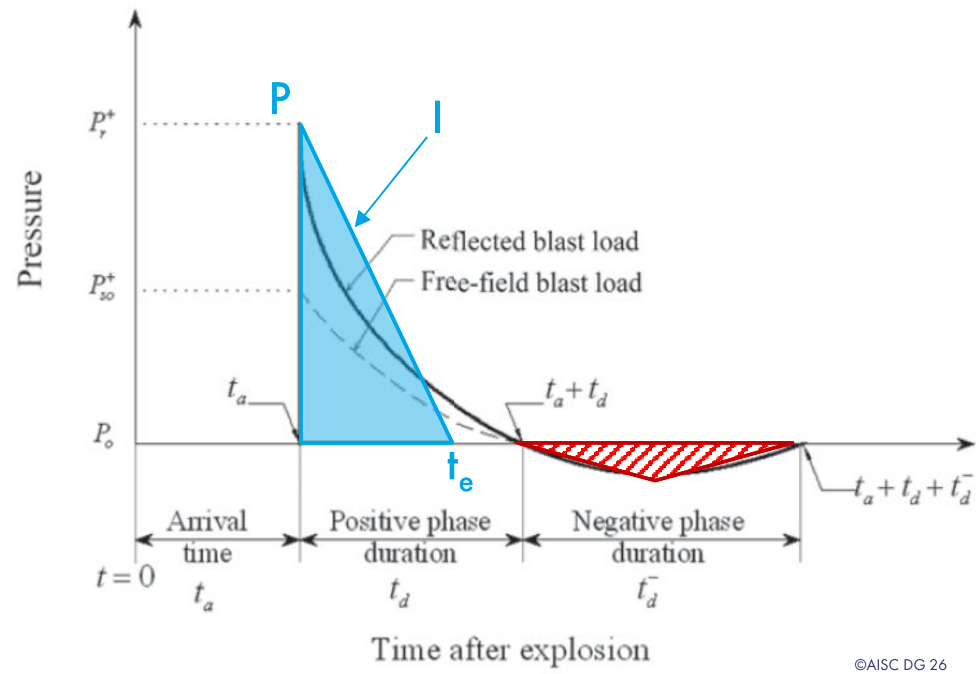
Blast Load Simplification

- **Pressure-time history positive phase**
  - Simplified to a triangular distribution w/ instantaneous rise and linear decay
  - Peak pressure and impulse are preserved
  - Fictious duration, $t_e = 2(I/P)$
- **Pressure-time history negative phase**
  - Neglected for this demonstration
  - Considered when elements are weaker in the reverse loading direction or for short natural periods compared to the load duration
- **Other considerations**
  - Drag forces due to wind (dynamic) pressures
  - Large openings to account for interior loads due to leakage
  - Shielding (load reduction) and reflection (load amplification)



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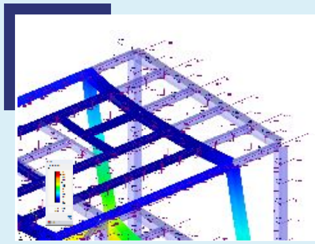
Dynamic Analysis Method Application in RFEM

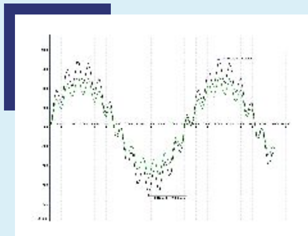
RF-/DYNAM Pro
Natural Vibrations

- Prerequisite Modal Analysis



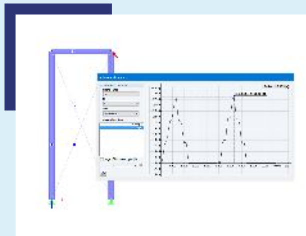
RF-/DYNAM Pro
Equivalent Loads

- Response Spectrum Analysis



RF-/DYNAM Pro
Forced Vibrations

- Limited RSA
- Accelerograms
- Linear Time History



RF-/DYNAM Pro
Nonlinear Time History

- Accelerograms
- Nonlinear Time History

AISC DG 26 – Example 2.1

Given:

- One-story steel building ; 50 ft x 70 ft x 15 ft
- Short direction – braced frames ; long direction – rigid frames
- Hot rolled sections ; ribbed metal panels
- Blast W = 500 lb ; R = 50 ft from structure

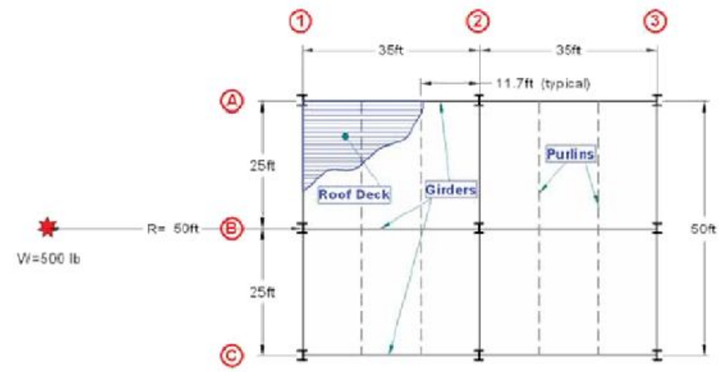


Fig. 2-9. Steel building—plan view.

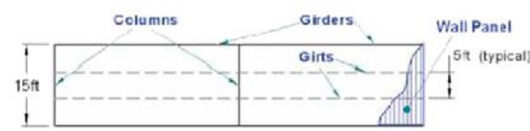


Fig. 2-10. Steel building—elevation.

AISC DG 26 – Example 2.1 (cont'd)

Solution:

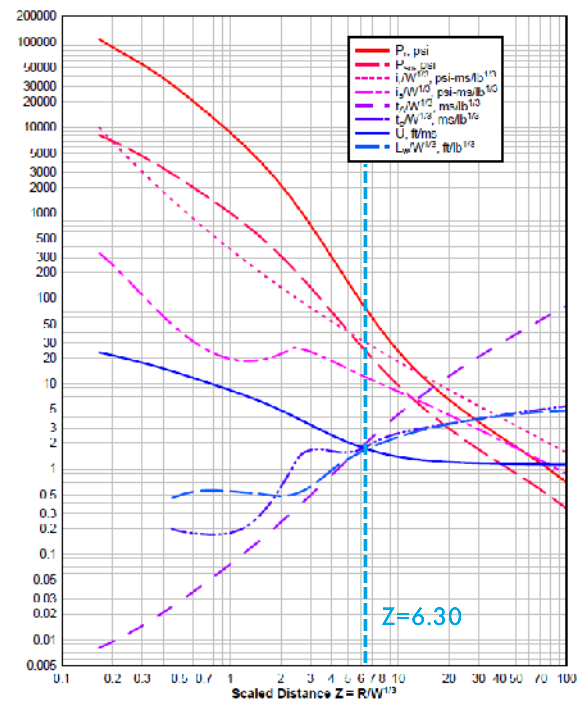
- Scaled distance

$$Z = \frac{R}{\sqrt[3]{W}} = \frac{50\ \text{ft}}{\sqrt[3]{500\ \text{lb}}} = 6.3\frac{\text{ft}}{\text{lb}^{\frac{1}{3}}}$$

- Parameters for blast loading (UFC 3-340-02)

Blast Loading Parameters	From Figure 2-15	Calculated
Reflected peak pressure (+)	P_r = 79.5 psi	–
Side-on peak pressure (+)	P_{so} = 24.9 psi	–
Reflected impulse (+)	$I_r = 31.0W^{1/3}$	I_r = 246 psi ms
Side-on impulse (+)	$I_{so} = 12.1W^{1/3}$	I_{so} = 96.0 psi ms
Time of arrival	$t_a = 1.96W^{1/3}$	t_a = 15.6 ms
Exponential load duration (+)	$t_d = 1.77W^{1/3}$	t_d = 14.0 ms
Shock front velocity	U = 1.75 ft/ms	–

Figure 2-15 Positive Phase Shock Wave Parameters for a Hemispherical TNT Explosion on the Surface at Sea Level



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AISC DG 26 – Example 2.1 (cont'd)

Reflected pressure (front wall):

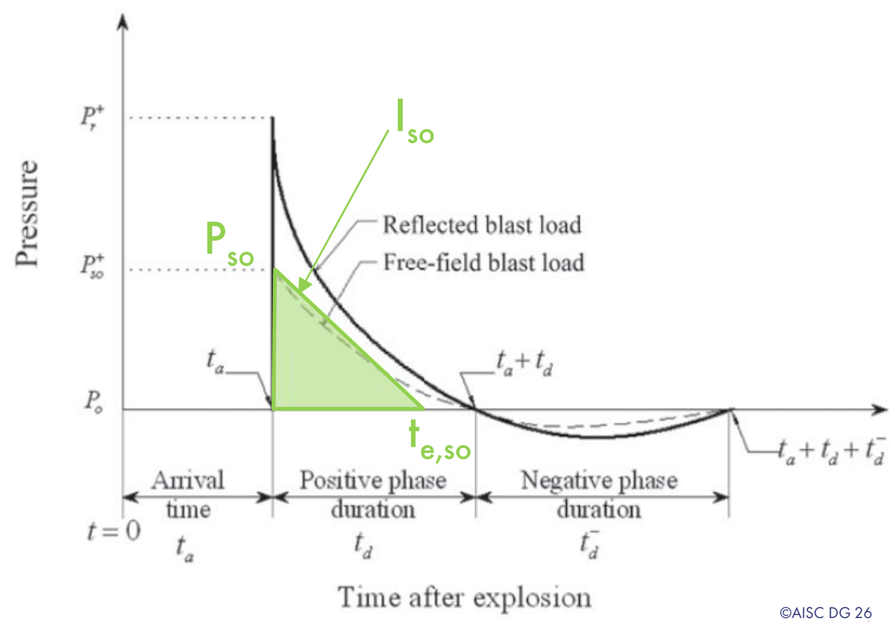
- Equivalent triangular shape with peak pressure (P_r) and impulse (I_r) values are preserved
- Equivalent duration for positive phase blast load for reflected pressure

$$t_{e,r} = \frac{2I_r}{P_r} = \frac{2(246 \text{ psi ms})}{29.5 \text{ psi}} = 6.19 \text{ ms}$$

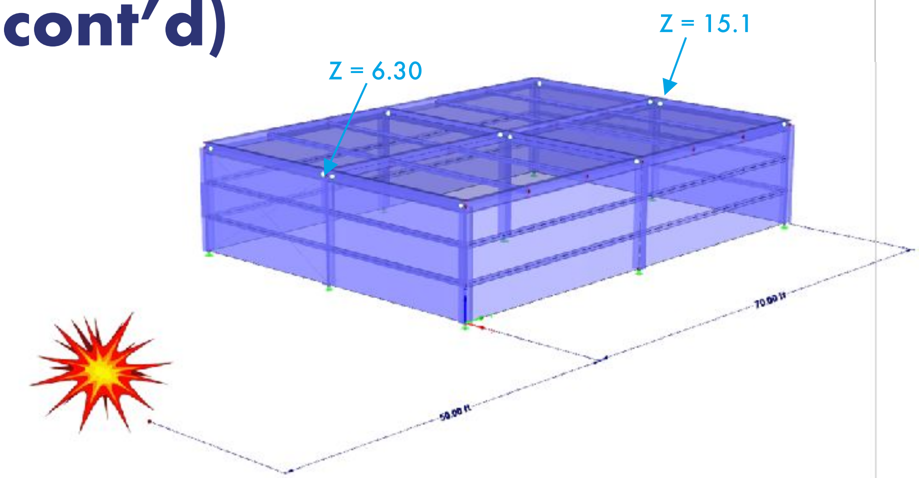
Side-on pressure (side wall and roof):

- Simplicity, use scaled distance, Z = front wall centerline for side walls and roof
- Equivalent duration for positive phase blast load for side-on pressure

$$t_{e,so} = \frac{2I_{so}}{P_{so}} = \frac{2(96.0 \text{ psi ms})}{24.9 \text{ psi}} = 7.71 \text{ ms}$$



AISC DG 26 – Example 2.1 (cont'd)



Rear Wall

- Charge distance, R = 50 ft + 70 ft = 120 ft
- Scaled distance, $Z = \frac{R}{\sqrt[3]{W}} = \frac{120\ \text{ft}}{\sqrt[3]{500\ \text{lb}}} = 15.1 \frac{\text{ft}}{\text{lb}^{\frac{1}{3}}}$
- Parameters for blast loading (UFC 3-340-02)
- Equivalent duration for positive phase blast load for side-on pressure

$$t_{e,so} = \frac{2I_{so}}{P_{so}} = \frac{2(44.0\ \text{psi ms})}{4.60\ \text{psi}} = 19.1\ \text{ms}$$

Blast Loading Parameters	From Figure 2-15	Calculated
Side-on peak pressure (+)	P_{so} = 4.60 psi	–
Side-on impulse (+)	$I_{so} = 5.54W^{1/3}$	I_{so} = 44.0 psi ms
Time of arrival	$t_a = 8.32W^{1/3}$	t_a = 66.0 ms
Exponential load duration (+)	$t_d = 3.11W^{1/3}$	t_d = 24.7 ms
Shock front velocity	U = 1.26 ft/ms	–

AISC DG 26 – Example 2.1 (cont'd)

Rear Wall (cont'd)

- Time of arrival, t_a = 66.0 ms
- Time to peak pressure, t_2

$$t_2 = \frac{L_1}{U} + t_a = \frac{15.0\text{ft}}{1.26\ \text{ft/ms}} + 66.0\ \text{ms} = 77.9\ \text{ms}$$

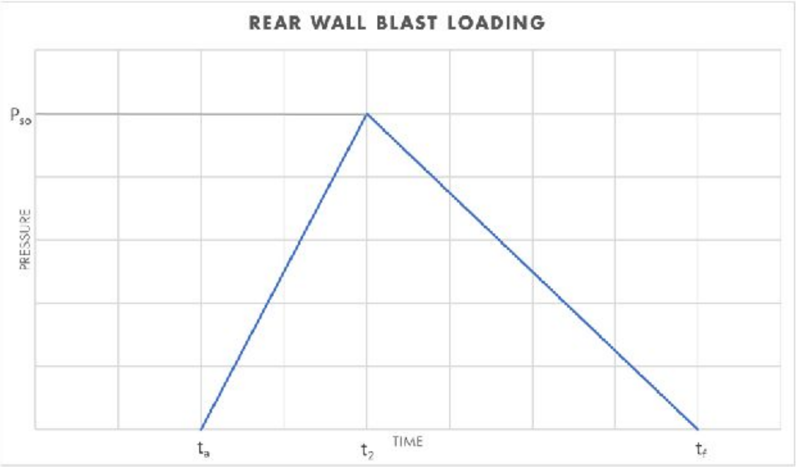
Where,

L_1 = span of element parallel to traveling wave
= building height (15 ft)

U = shock front velocity (UFC 3-340-02 Figure 2-15)

- Time to end of blast load (+), t_f

$$t_f = t_2 + t_{e,so} = 77.9\ \text{ms} + 19.1\ \text{ms} = 97.0\ \text{ms}$$

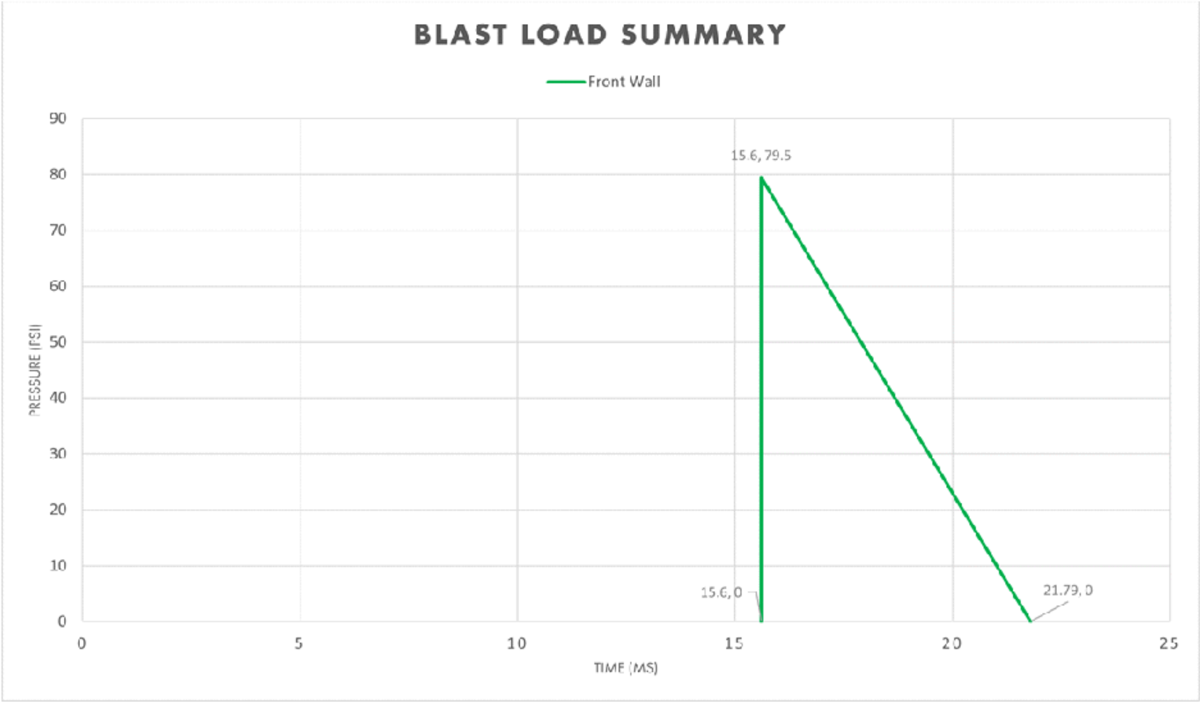


AISC DG 26 – Example 2.1 (cont'd)

Blast Load Summary

- Plot showing pressure vs. time of blast wave for front, side/roof, and rear walls
- Equivalent triangular loading function used over more exact loading function
- Negative phase of shock and other variables (dynamic pressure, openings, etc.) not included
- For simplicity, full side-on pressures computed for nonreflected surfaces (side walls, roof, rear wall) rather than load averaging techniques in UFC 3-340-02

AISC DG 26 – Example 2.1 (cont'd)



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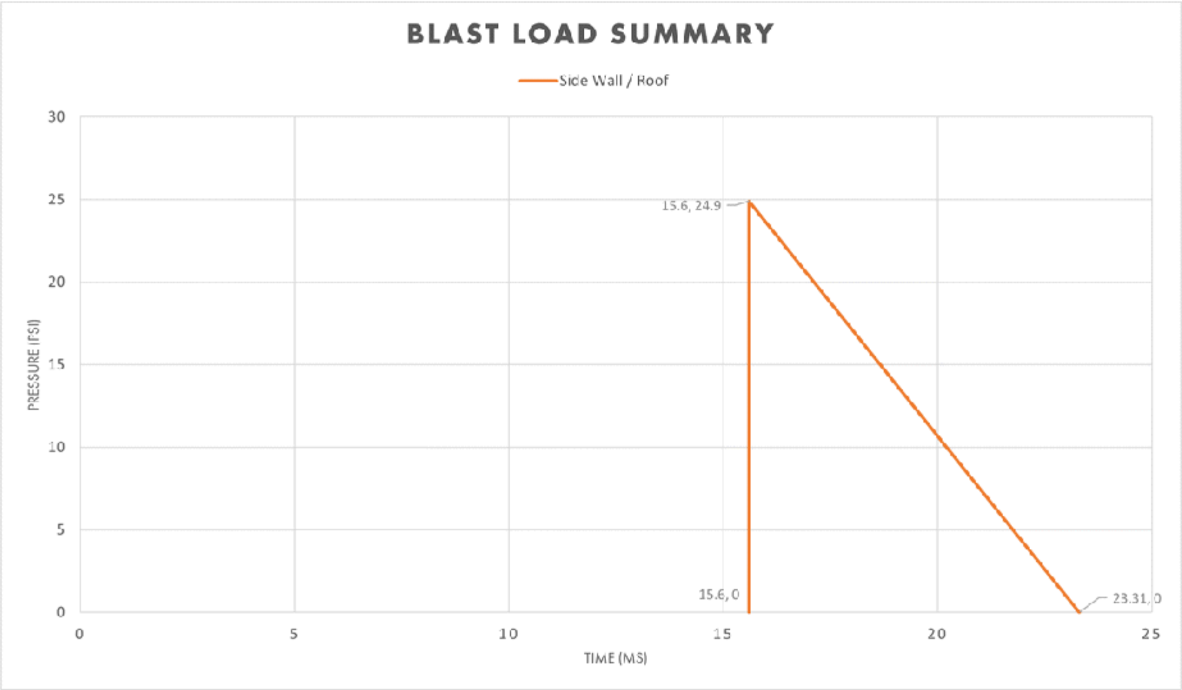

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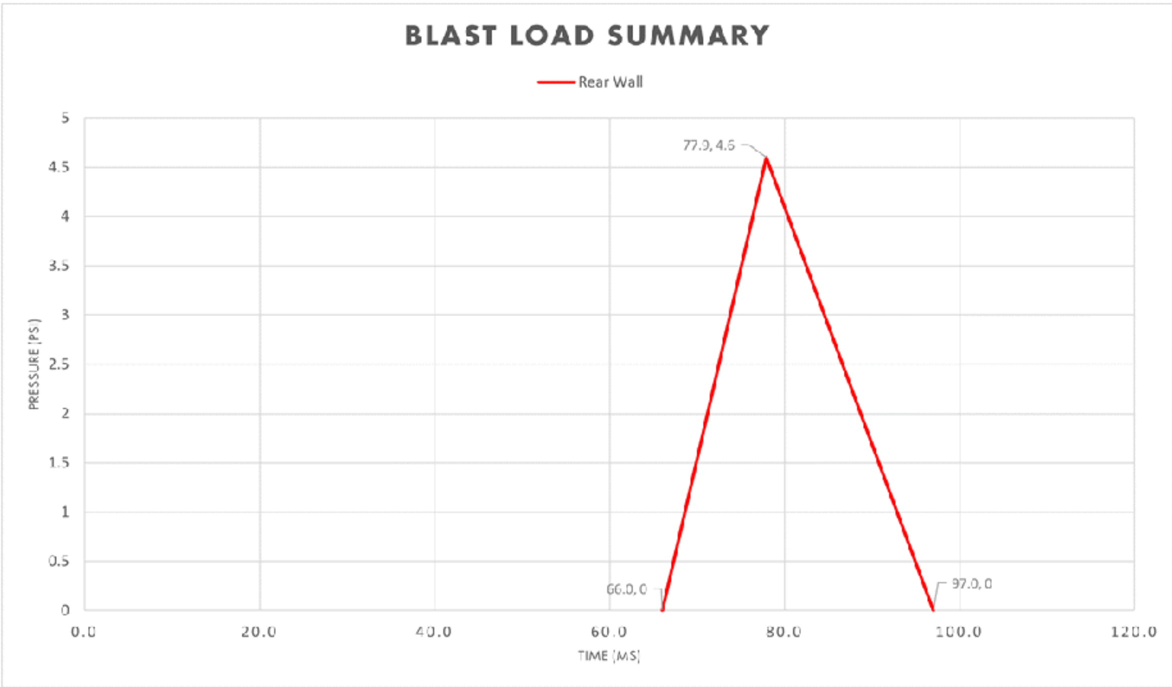

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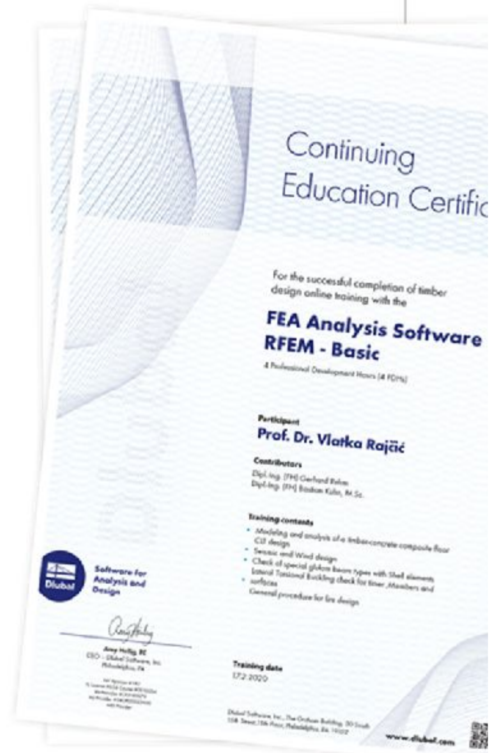

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