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U.S. ARMY CORPS OF ENGINEERS
PROTECTIVE DESIGN CENTER TECHNICAL REPORT

Example Problems for SBEDS (Single-Degree-of-Freedom Blast Effects Design Spreadsheets)

Prepared for:

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1. INTRODUCTION

SBEDS (Single degree of freedom Blast Effects Design Spreadsheet) is an EXCEL® workbook that is distributed by the U.S. Army Corps of Engineers, Protective Design Center (PDC) as a tool to design structural components to resist blast loads. It is designed to run in a broad range of Windows® operating systems, including Vista and XP. General information on the distribution, development, and terms of use of SBEDS is provided on the *Readme* worksheet in the SBEDS workbook (the first worksheet in the workbook).

SBEDS is based on the assumption that the designed component can be idealized as an equivalent SDOF (single-degree-of-freedom) system. It is intended for users possessing a reasonable knowledge of structural engineering, dynamic response, and blast effects. The user must be capable of understanding the effects of the various inputs and recognizing situations that may produce erroneous results. The use of the SDOF approach for analysis and design of blast-loaded structural components is discussed in many textbooks and blast design manuals from the U.S. government and industry organizations. These are referenced in the SBEDS Methodology Manual, which is distributed with SBEDS and installed into the same directory on the computer hard drive as the SBEDS workbook.

This manual contains a collection of example problems that demonstrate use of SBEDS. It is organized in terms of a section on the general use of SBEDS, which contains user information that is applicable to all analysis and design with SBEDS, and twenty-four examples that are specific to given structural component types in SBEDS. These examples are in both Metric and English units.

2. GENERAL INFORMATION ON USE OF SBEDS

Intro Worksheet

As a first step to each analysis, the users should go to the *Intro* worksheet (see worksheet tabs at bottom of Excel window) and go to the top left hand corner of this sheet to see the area shown in Figure 1.

First time users should read the notes located below the Initiate Component button on the *Intro* sheet. To begin an analysis, the user must select the component type of interest and units of interest and then click on the large grey button to initiate component input. This will run a macro that opens up a companion spreadsheet in the same directory on the computer hard drive as SBEDS.xls called SBEDS_templates.xls, retrieve an appropriate input form for the selected component type and units from SBEDS_templates.xls and insert it onto the Input sheet in SBEDS.xls. As a last step the macro will place the user on the new *Input* sheet in SBEDS with the correct input form.

General Format of Input Worksheet

All input forms are identical for the first 5 rows, as shown in Figure 2 .

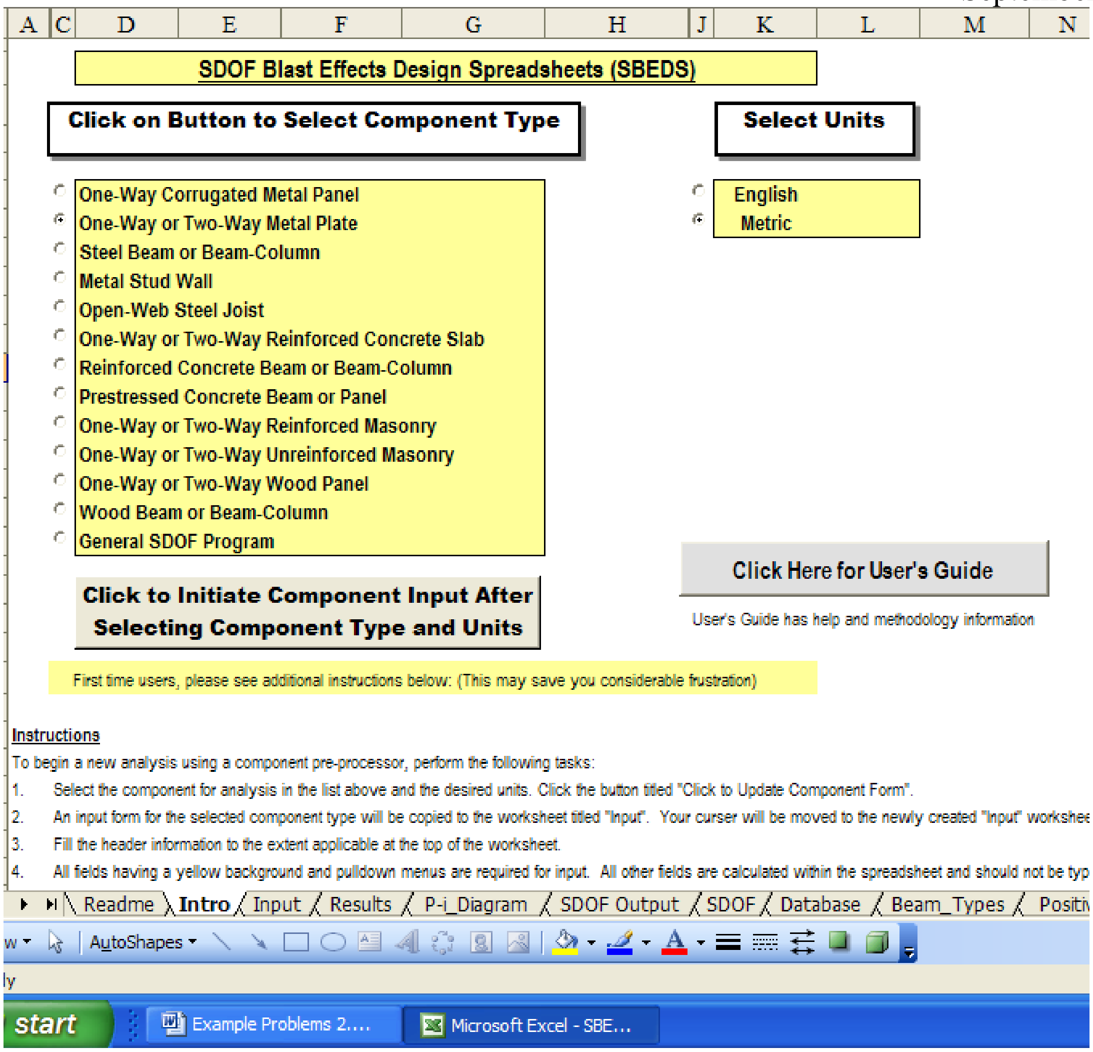


Figure 1. Intro Worksheet Area where User Defines Component Type and Units

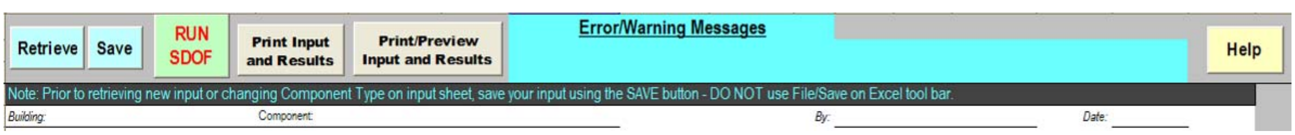


Figure 2. Area at Top of Input Worksheet

The buttons shown in Figure 2 are always shown at the top of the Input sheet:

- **Save** will save existing component input information on the current *Input* sheet to a user defined file on the hard drive. *Use this command to save input information – do not use the File/Save command in EXCEL.* The Save button will save a small file with only the component input information rather than the entire 14 MB SBEDS workbook.
- **Retrieve** will retrieve saved component input information from a file on the hard drive (note that a previously saved file with input information for any component type and units can be retrieved at any time).
- **RUN SDOF** calculates the dynamic response of the blast-loaded component defined on the current *Input* sheet.

- **Print Input and Results** causes the component and blast load input and the summarized SDOF response information on the *Input* sheet along with detailed SDOF response information on the *Results* sheet to be printed to the default printer.
- **Print/Preview Input and Results** is the same as the Print Input and Results capability except this button uses the Print/Preview function of EXCEL so that a user can reformat the print and select a printer.
- **Help** displays a linked pdf file with detailed information on all input values in SBEDS that is organized by component type. The pdf file also contains the SBEDS Methodology Manual with detailed information on the methods used in SBEDS to calculate blast loads and SDOF response of input components. (The linked pdf file is in the same directory on the computer hard drive where SBEDS.xls is installed.)

The other rows on the input forms have input that is component type dependent, as explained in the following example problems. All yellow cells and dropdown boxes on the input forms should generally be filled in by the user (inputs where zero is acceptable do not need to be filled in).

Usage of Input Worksheet

After all the input is completed, click the "RUN SDOF" button at the top of the *Input* sheet. This will cause a macro to determine the response of the equivalent SDOF system for the input blast-loaded component as defined in the SDOF Properties section on the *Input* sheet. The SBEDS workbook solves the equation of motion for this equivalent SDOF system, subject to a blast load based on the user input, with a time-stepping approach using numerical integration.

A message will be displayed indicating the SDOF calculations are complete. The user should then *<u>check for any error/warning messages</u>* at the top of the *Input* sheet and then page down to see the Results Summary section. The user should also go to the *Results* sheet to see the full calculated response histories for the component. All the plotted data points on the *Results* sheet are shown on the *SDOF Output* sheet, along with SAVE buttons that can be used to save this information into DPLOT compatible files. The dynamic reaction histories on the *SDOF Output* sheet can also be saved into files that can be read as applied pressure-time histories into subsequent SBEDS analyses of supporting components.

SBEDS calculates the maximum reaction at each support and the shear capacity (for most component types) of the input component and displays this information on the *Input* sheet under the Results Summary section. The maximum reaction is compared to the shear capacity and a cell displays a message indicating that Shear is OK (i.e., maximum reaction force does not exceed the component shear capacity) or that Shear is Not OK. For many component types, the user is given an option to rerun the SDOF analysis based on shear-controlled response if the shear is not okay. This is demonstrated in the example problems.

3. EXAMPLE PROBLEMS

The following sections of this manual show a range of example problems where SBEDS is used to perform SDOF analysis of each component type subject to blast loads defined in each manner possible in SBEDS. Table 1 summarizes these example problems.

Table 1. Summary Information for SBEDS Example Problems

No.	Component Type	Unit	Load Type[1,2,3]	Response Mode[4]	Boundary Conditions	Component Description	Span	Spacing	LOP	LOP Subgroup
1A	One-Way Corrugated Metal Panel	English	Manual	Flexure	F-S	1.5C24 roof panel supporting 1 psf	5 ft	N/A	LLOP/ Secondary	Limited TM Capacity
1B		Metric	W-R, Reflected w/ Clearing on 3m x 20m wall area	Flexure w/ Tension Membrane	F-S	38 C 0.6 mm wall panel supporting 15 kg/m^2	2 m	N/A	LLOP/ Secondary	Full TM Capacity
2A	One-Way or Two-Way Steel Plate	English	W-R, Fully Reflected	Flexure	Two Way F-F	3/8” thick steel plate w/ User Defined properties	4 ft x 4 ft	N/A	HLOP/ Secondary	All plates
2B		Metric	W-R, Fully Reflected w/ Negative Phase	Flexure	S-S-S-S	9.5 mm thick 6061 T6 aluminum plate	1 m x 1 m	N/A	MLOP/ Secondary	All plates
3A	One-Way Open-Web Steel Joist	English	Pressure-history using dynamic reaction from Example 1A	Flexure *(Time step issues also discussed)*	S-S	12K1 joist supporting 3 psf	25 ft	5 ft	MLOP/ Secondary	Downward flexure
3B		Metric	W-R, Side-on	Flexure	S-S	24LH04 supporting 10 kg/m^2	6.5 m	6 m	LLOP/ Secondary	Downward flexure
4A	One-Way Steel Beam or Beam-Column	English	Manual	Flexure w/ Tension Membrane	F-S	Roof purlin with User Defined cross section and material properties supporting 3 psf	25 ft	5 ft	LLOP/ Secondary	Cold-formed girts & purlins
4B		Metric	W-R, Reflected with α = 20 deg	Flexure with Significant Static Axial Load	F-S	UC 203x203x86 column with 2% damping	4.5 m	6.5 m	LLOP/ Primary	Combined Flex &Comp - compact section
5A	Metal Stud Wall	English	Pressure-history file with multi-peak blast load and dynamic axial load from Example 3A	Flexure with Significant Dynamic Axial Load	S-S	800S250-68 steel studs supporting 2 psf	10 ft	0.5ft	LLOP/ Primary	Connected top, bottom
5B		Metric	Manual	Flexure w/ Tension Membrane	S-S	600S200-43 steel studs supporting 100 mm veneer brick wall anchored w/ full TM capacity of stud	3 m	0.4 m	LLOP/ Secondary	Flexure and TM
6A	One-Way or Two-Way Reinforced Concrete Slab	English	Manual	Flexure with and without Shear controlled response	F-F-F	8 inch wall with #6 rebar EFEW at 12” o.c., (SHEAR Controlled)	20 ft x 12 ft high	N/A	MLOP/ Secondary	Flexure-no shear reinf. or TM
6B		Metric	W-R, Fully Reflected w/ Negative Phase.	Flexure w/ Tension and Compression Membrane	F-F-F-F	305 mm wall with 12.5 mm rebar EFEW at 300 mm at each face of wall w/ shear stirrups	7 m x 4 m high	N/A	LLOP/ Secondary	Flexure-shear reinf. and TM

No.	Component Type	Unit	Load Type[1,2,3]	Response Mode	Boundary Conditions	Component Description	Span	Spacing	LOP	LOP Subgroup
7A	One-Way Reinforced Concrete Beam or Beam-Column	English	Manual	Flexure w/ Tension Membrane, Type II cross section	F-F	12 in x 12 in roof joist w/ 3#5 bottom and 2#6 top flexural steel, shear stirrups, supporting 4 in slab	25 ft	7 ft	LLOP/ Secondary	Flexure-shear reinf. and TM
7B		Metric	Manual	Flexure with Significant Static and Dynamic Axial Load	F-S with conc. load at midspan, A_f=0.5	460 mm square column w/ 4-19 mm dia. (total) rebar, stirrups, supporting 150 mm wall slab	4 m	7 m	LLOP/ Primary	F&C-shear reinforcing, no TM
8A	One-Way Prestressed Concrete Beam or Panel	English	W-R, Side-on	Flexure	S-S	Tee beam - 25 in x 4.8 in stem and 3 in w/ 2-0.5 in dia. bonded Grade 270 prestressing strands and 3 in slab w/ 0.29 in^2 WWF	40 ft	4 ft	LLOP/ Secondary	$w_p < 0.15$
8B		Metric	Pressure-history using saved CONWEP/DPLOT file run for same W-R as English case	Flexure	S-S	Tee beam - 635 mm x 122 mm stem w/ 2-12.5 mm dia. bonded Grade 270 prestressing strands and 75 mm slab w/ 187 mm^2 WWF	12.2 m	1.2 m	LLOP/ Secondary	$w_p < 0.15$
9A	One-Way or Two-Way Reinforced Masonry	English	W-R, Side-on w/ Negative Phase	Flexure	S-S with blast resistant windows (B_w=0.5)	8 in lightwt CMU wall partially grouted w/ #5 rebar at 16 in at midthickness.	12 ft	N/A	LLOP/ Secondary	Flexure
9B		Metric	Manual	Flexure with Static Axial Load	S-S-S-S	305 mm European block wall w/ 12.5 mm dia rebar EW at 406 mm on center at midthickness	3 m x 5m	N/A	LLOP/ Primary	Combined Flexure & Compression
10A	One-Way or Two-Way Unreinforced Masonry	English	W-R, Reflected, α = 50 deg. w/ Negative Phase	Brittle flexure and axial load arching, 2% damping	S-S	8 in lightwt CMU wall, ungrouted	10 ft	N/A	LLOP/ Secondary	Flexure
10B		Metric	Manual	Rigid Arching, 2% damping	S-S	150 mm European block wall	3 m	N/A	MLOP/ Secondary	Flexure

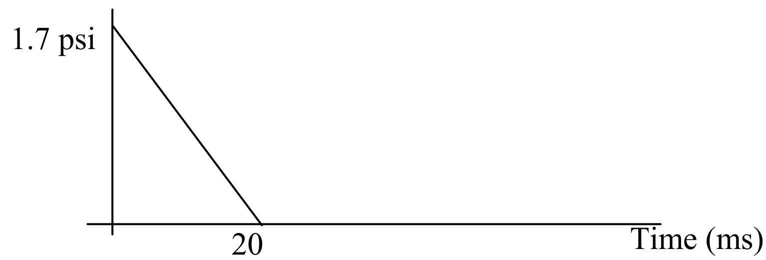
No.	Component Type	Unit	Load Type[1,2,3]	Response Mode	Boundary Conditions	Component Description	Span	Spacing	LOP	LOP Subgroup
11A	One-Way or Two-Way Wood Panel	English	Manual	Flexure	S-S-S-S	0.75 in thick plywood panel	6 ft x 6 ft	N/A	LLOP/ Secondary	Flexure
11B		Metric	Manual	Flexure	S-S	12.5 mm thick plywood panel	1.5 m	N/A	HLOP/ Secondary	Flexure
12A	One-Way Wood Beam or Beam-Column	English	W-R, Reflected, α = 30 deg. w/ Clearing on 33 ft x 33 ft wall area	Flexure	S-S	2x4 No. 2 Spruce wall studs	10 ft	1.33 ft	LLOP/ Secondary	Flexure
12B		Metric	Manual	Flexure with Static **Axial** Load	S-S w/ conc. midspan load, Loaded Area Factor A_f=0.5	150 mm x 150 mm No. 1 Hem-Fir column with 160 KN axial load	3 m	3 m	MLOP/ Primary	Combined Flexure & Compression
13A	General SDOF Program	English	Manual	N/A	N/A	Equivalent SDOF system representing indeterminate component in flexure	N/A	N/A	N/A	N/A
13B		Metric	W-R, Reflected, w/ Negative Phase	N/A	N/A	Equivalent SDOF system representing component in combined flexure, tension and compression membrane	N/A	N/A	N/A	N/A

Notes:

1) W-R is load defined by input of equivalent TNT charge weight and standoff into SBEDS. All W-R cases are positive phase blast load only UNO.
2) All Reflected W-R cases are at angle of incidence (α) equal to zero (fully reflected) with no clearing UNO.
3) All examples have no damping UNO.
4) All examples with reinforced concrete and masonry are Type I cross section UNO.

Example 1A: Corrugated Steel Panel (English)

A 1.5-inch deep 24 ga. corrugated roof panel is subjected to the pressure load that is defined as an equivalent triangular load with only the positive phase blast pressure as shown below:



The building requires a Low Level of Protection (LLOP) and the panel is classified as a secondary type component. The panels will be directly attached to the supporting purlins with standard #12 self-drilling screws spaced at 12 inches on center. In addition to the blast load above, the panel is assumed to have the following design parameters:

- One-way span length L = 5 ft
- Supported Weight = 1 lb/ft^2
- Fixed-Simple supports
- 1.5C24 corrugated steel panel
- Provide LLOP as a secondary component

Solution

The user should go to the *Intro* worksheet, click the radio button for One-Way Corrugated Metal Panel and for English units and then click on the large grey button to Initiate Component Input. After the macro runs, the user will be placed on the *Input* sheet with the input form for a One-Way Corrugated Metal Panel. The yellow cells and drop down boxes in the input form should be filled out as shown below.

The input shown below reflects the previously defined properties of the panel and blast load. In this case, we will conservatively assume there is no damping. The gravity displacement is in the direction of the blast load for the roof panel. The recommended time step displayed by SBEDS will be input. The Blast Load Input Type is “Manual input” because the blast load will be defined by input Time, Pressure points as shown in the input below. The dropdown boxes associated with Charge Weight and Standoff on the input form do not apply for this case since they are only used if the Blast Load Input Type is set to “Charge weight and standoff”.

The Response Criteria information on the input form is based on the panel connections and the previously discussed building LOP and component type (i.e., secondary). It will be assumed that the screws and supports provide limited tension membrane (TM), so “Limited TM Capacity” is selected under Response Criteria on the *Input* sheet and “LLOP/Secondary – NS” is selected as the LOP type. The SBEDS program displays the maximum allowable Support Rotation and Ductility Ratio from response criteria defined by the U.S. Army Corps of Engineers, Protective Design Center (PDC) for the input Response Criteria information, as shown below.

One-Way Corrugated Metal Panel

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

Span, L:	5	ft
Boundary Conditions:	Fixed-Simple, Uniformly Loaded	
Response Type:	Flexural	

Structural & Material Properties

Select Panel Type:	1.5C24 (Vulcraft)	
Self-Weight, w:	1.54	psf
Nominal Thickness, t:	0.0239	in
Rib Height, h:	1.5	in
Rib Spacing, b:	6	in
Moment of Inertia, I:	0.122	in^4/ft
Section Modulus, S:	0.126	in^3/ft
Supported Weight, W:	1	psf
Yield Strength, f_y:	50,000	psi
Elastic Modulus, E:	29000000	psi
Static Strength Increase Factor:	1.21	
Dynamic Increase Factor:	1.1	
Dynamic Yield Stress, f_{dy}:	66,550	psi
Cross sectional area, A:	0.038	in^2/in
Leave Blank	0	

Click for User Defined Panel

Calculated Properties

Moment Capacity:	628.9	lb-in/in

Blast Load Input Type

Manual input

Gravity Displacement

In direction of blast load

Pressure-Time Input

Time (ms)	Pressure (psi)
0	1.7
20	0
25	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (lbs TNT)	R (ft)

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected with Clearing

Parameters for Reflected Loads

Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	

See notes under error messages

Load file name

Applied Blast Input File Not Selected

Response Criteria

Limited TM capacity

LOP/Type: LLOP/Secondary-NS

θ (deg)	μ
2	3

See All COE Response Criteria

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (simple support) =	0.08	0.12
R (simple support) =	0.29	0.30
F (fixed support) =	0.19	0.12
R (fixed support) =	0.43	0.46

Solution Control

Inbound Natural Period:	18.28	ms
Rebound Natural Period:	18.28	ms
Recommended Time Step:	0.05	ms
Time Step:	0.05	ms
% of Critical Damping:	1	%
Initial Velocity:	0	in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	45.6	45.6	psi-ms²/in
Load-Mass Factors, K_{LM}			
K_{LM1}	0.78	0.78	
K_{LM2}	0.78	0.78	
K_{LM3}	0.66	0.66	
Stiffness, K			
K_1	4.21	4.21	psi/in
K_2	1.75	1.75	psi/in
K_3	0.00	0.00	psi/in
Resistance, R			
R_1	1.40	-1.40	psi
R_2	2.10	-2.10	psi
Yield Displacement, x			
x1	0.33	-0.33	in
x2	0.73	-0.73	in
Equiv Yield Defl., X_E	0.58	-0.58	in

Note that the limited tension membrane capacity only refers to the response criteria category. The tension membrane is sufficient to compensate for a reduction in moment capacity due to local buckling of the panel (i.e., kinking) in the maximum moment region, and this allows a larger response for given damage levels than would otherwise by allowed. However, the tension membrane behaviour is not considered sufficient to also cause an increase in resistance at larger deflections. Therefore, tension membrane response is not explicitly modeled in SBEDS in this case.

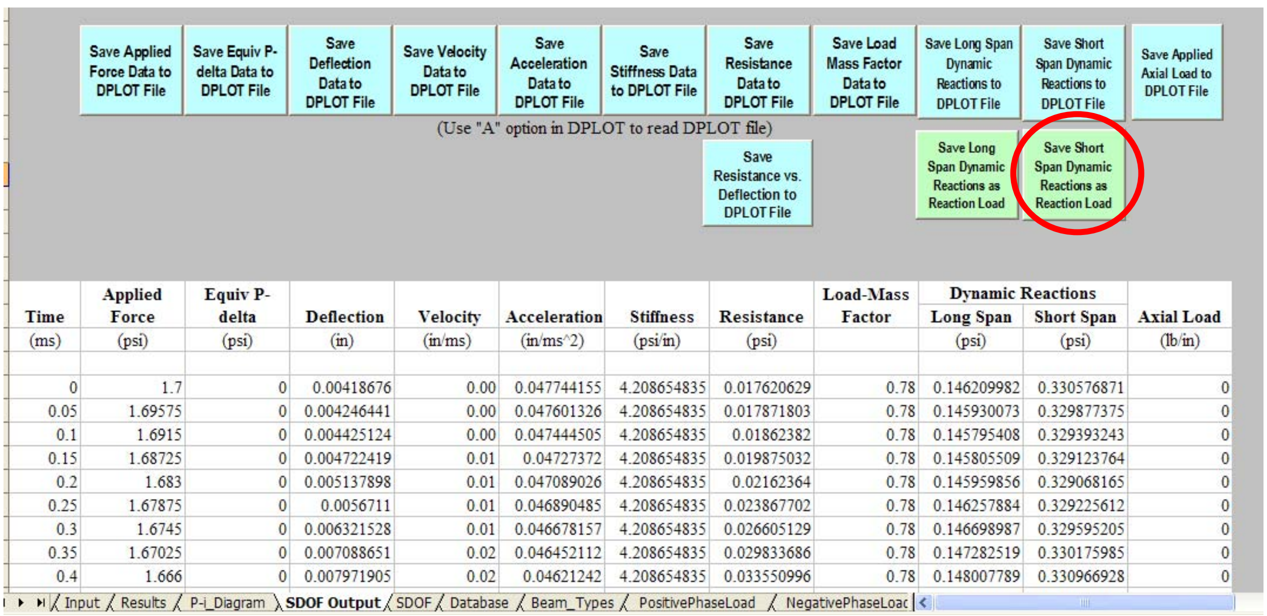
Detailed information on this response criteria can be accessed through a linked pdf file by clicking on the See All COE Response Criteria button on the *Input* sheet next to the Response Criteria input section.

After all the input is completed as shown above, click the "RUN SDOF" button at the top of the *Input* sheet and inspect the results as explained in the initial section of this manual on general use of SBEDS. As shown in the Results Summary shown below, the calculated maximum dynamic displacement of the panel is 0.75 inches. The output indicates that this corresponds to a ductility ratio of 1.3 and a support rotation of 1.4 degrees. Therefore, it is within the allowable response criteria of a ductility ratio of 3 and a support rotation of 2 degrees, as noted in the Results Summary. Note that the calculated response must meet both the ductility ratio and support rotation criteria.

SBEDS calculates the maximum reaction at each support (V_u,L and V_u,R) and the shear capacity of the panel, as shown below. The maximum reaction does not exceed the shear capacity, as indicated by the message that "Shear is OK". As noted, the maximum reaction forces are assumed to be caused only by flexural response. *The user must separately consider connection forces caused by any tension membrane response when this response mode is modeled in SBEDS.* Information on all the calculated response histories is shown on the Results sheet, as explained in the initial section of this manual on general use of SBEDS.

Results Summary					
θ_{max} =	1.43	deg.	Design Criteria:	LLOP/Secondary-NS	
μ =	1.30		Response OK compared to input design criteria		
X_{max} Inbound =	0.75	in	at time =	9.70	msec
X_{min} Rebound =	-0.02	in	at time =	20.05	msec
R_{max} =	2.10	psi	at time =	9.70	msec
R_{min} =	-1.14	psi	at time =	20.05	msec
Shortest Yield Line Distance to Determine θ:				30.0	in
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
V_uL =				79	lb/in
V_uR =				47	lb/in
Shear Capacity					
Shear Area: A_v=				0.0120	in^2/in
Shear Capacity: V_s =				176	lb/in
Results based on Max Shear			Shear is OK		
* Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.					

The dynamic reaction pressure history for this panel will be saved to a file and used as the applied blast load on an open web steel joist that supports the panel in Problem 3A. This reaction history is an out-of-plane reaction at the component supports, and therefore does not include any in-plane effects from cases such as tension membrane. One complete cycle of the reaction history, including rebound, is saved to the designated file. Rebound occurs due to the natural tendency of the structural component to rebound from dynamic load from loads that have only positive phase blast load and combined positive and negative phase blast load. This reaction pressure history does include out-of-plane effects from any tension membrane response, since this increases the resistance and the reaction history is calculated in large part based on the component resistance at each time step. Go to the SDOF Output sheet in SBEDS and click on the green button to Save Short Span Dynamic Reaction Load (the larger of the two Dynamic Reactions). SBEDS will save dynamic reaction pressure and corresponding time step to a *.dat file. As stated in a message box, the reaction pressures shown on the Output Sheet are automatically multiplied by two in the save file routine as explained in Chapter 3 of the SBEDS Methodology Manual. The saved dynamic reaction pressures can be applied as a blast load on a supported component in SBEDS, where the saved reaction pressure history multiplied by the components spacing or supported width will equal the dynamic reaction load along the span of the supporting component.



Time	Applied Force	Equiv P-delta	Deflection	Velocity	Acceleration	Stiffness	Resistance	Load-Mass Factor	Dynamic Reactions Long Span	Dynamic Reactions Short Span	Axial Load
(ms)	(psi)	(psi)	(in)	(in/ms)	(in/ms^2)	(psi/in)	(psi)		(psi)	(psi)	(lb/in)
0	1.7	0	0.00418676	0.00	0.047744155	4.208654835	0.017620629	0.78	0.146209982	0.330576871	0
0.05	1.69575	0	0.004246441	0.00	0.047601326	4.208654835	0.017871803	0.78	0.145930073	0.329877375	0
0.1	1.6915	0	0.004425124	0.00	0.047444505	4.208654835	0.01862382	0.78	0.145795408	0.329393243	0
0.15	1.68725	0	0.004722419	0.01	0.04727372	4.208654835	0.019875032	0.78	0.145805509	0.329123764	0
0.2	1.683	0	0.005137898	0.01	0.047089026	4.208654835	0.02162364	0.78	0.145959856	0.329068165	0
0.25	1.67875	0	0.0056711	0.01	0.046890485	4.208654835	0.023867702	0.78	0.146257884	0.329225612	0
0.3	1.6745	0	0.006321528	0.01	0.046678157	4.208654835	0.026605129	0.78	0.146698987	0.329595205	0
0.35	1.67025	0	0.007088651	0.02	0.046452112	4.208654835	0.029833686	0.78	0.147282519	0.330175985	0
0.4	1.666	0	0.007971905	0.02	0.04621242	4.208654835	0.033550996	0.78	0.148007789	0.330966928	0

Example 1B: One-way Corrugated Metal Panel (Metric)

Check the response of a 38 C 0.6mm corrugated wall panel against 40kg of TNT at 36 m of standoff. Include clearing effects for an effective wall area that is 3m high x 20m wide. The connections to the support can develop a tension force of 32N/mm in the panel. The panel requires LLOP and is considered a secondary type component. 1% damping will be assumed for this analysis, although it is not expected to have much effect on the results.

The panel is assumed for design to have the following conditions:

- One-way span length L = 2 m
- Supported Weight = 15 kg/m^2
- Fixed-Simple supports
- 38 C 0.6mm panel size
- Reflected blast load from 40kg of TNT at 36 m
- Clearing over 3 m high x 20 m wide wall area subject to reflected blast load. This is the area of the whole building wall where the analyzed component is located.
- Flexure with tension membrane response with a connection/support tension capacity of 32 N/mm
- Provide LLOP as a secondary component
- Respond to blast load with 1% of critical damping

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way Corrugated Metal Panel" and metric units, and click on the button to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) using the information given in the problem statement. For this particular problem:

- Set the response type to "Flexural and Tension Membrane."
- Use 32N/mm for the support capacity for Tension Membrane, V_c.
- Under Blast Load Input Type at the top of the screen, select "Charge weight and standoff". This will gray out the cells in the Pressure-Time input box and enable the charge weight and standoff input box.
- In charge weight and standoff input box select "Reflected with Clearing" under Charge Weight Load Type and enter the height and width of the area subject to clearing in the designated cells. The angle of incidence is always zero for a fully reflected blast load, and this is a conservative assumption when no specific information for the angle of incidence is known. A blank input for the angle of incidence is equal to an input of zero.
- The Gravity Displacement dropdown near the top center of the input sheet is set to "None" since the panel is on a wall and does not have any displacement from gravity effects.
- Set the Dynamic Axial Load input cell to "No Dynamic Axial Load"

Next, set the Response criteria to "Full TM capacity" to account for Tension Membrane and select LLOP/Secondary-NS for LOP and type. Finally, go to the solution control box, and make sure the time step selected is less or equal than the recommended value. After all the inputs are entered, the input sheet should look as illustrated next.

One-Way Corrugated Metal Panel

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

Span, L:	2000	mm
Boundary Conditions:	Fixed-Simple, Uniformly Loaded	
Response Type:	Flexural and Tension Membrane	

Structural & Material Properties

Select Panel Type:	38 C 0.6mm thick (Vulcraft)	
Self-Weight, w:	7.50	kg/m^2
Nominal Thickness, t:	0.6	mm
Rib Height, h:	38.1	mm
Rib Spacing, b:	152.4	mm
Moment of Inertia, I:	167	mm^4/mm
Section Modulus, S:	6.775	mm^3/mm
Supported Weight, W:	15	kg/m^2
Yield Strength, f_y:	345	MPa
Elastic Modulus, E:	200,000	MPa
Static Strength Increase Factor:	1.21	
Dynamic Increase Factor:	1.10	
Dynamic Yield Stress, f_{dy}:	459	MPa
Cross sectional area, A:	0.96	mm^2/mm
Support Capacity for Tension Membrane, Vc:	32	N/mm

Click for User Defined Panel

Calculated Properties

Moment Capacity:	2,799.9	N-mm/mm

Blast Load Input Type

Charge weight and standoff

Blast Load Direction

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (kPa)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (kg TNT)	R (m)
40	36

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected with Clearing

Parameters for Reflected Loads

Wall Height (m)[1]	3
Wall Width (m)[1]	20
Incidence Angle[2]	0

See notes under error messages

Load file name

Applied Blast Input File Not Selected

Response Criteria

Full TM caacity

LOP/Type	LLOP/Secondary-NS

θ (deg)	μ
6	6

See All COE Response Criteria

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (simple support) =	0.08	0.12
R (simple support) =	0.29	0.30
F (fixed support) =	0.19	0.12
R (fixed support) =	0.43	0.46

Solution Control

Inbound Natural Period:	45.55	ms
Rebound Natural Period:	45.55	ms
Recommended Time Step:	0.13	ms
Time Step:	0.05	ms
Critical Damping:	1	%
Initial Velocity:	0	mm/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	22.50	22.50	kg/m^2
Load-Mass Factors, K_{LM}			
K_{LM1}	0.78	0.78	
K_{LMe}	0.78	0.78	
K_{LMe}	0.66	0.66	
Stiffness, K			
K_1	0.33	0.33	kPa/mm
K_2	0.00	0.00	kPa/mm
K_3	0.06	0.06	kPa/mm
Resistance, R			
R_1	8.40	-8.40	kPa
R_2	8.40	-8.40	kPa
Yield Displacement, x			
x1	25.15	-25.15	mm
x2	41.62	-41.62	mm
Equiv Yield Defl., X_E	25.15	-25.15	mm

After the input sheet is completed, click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the panel. As shown in the Results Summary shown below, the calculated maximum dynamic displacement of the panel is 95.06mm, which corresponds to a ductility ratio of 3.78 and a support rotation of 5.4 degrees. As stated in the Results Summary, this response is within the allowable limits for the selected LOP and the panel design is satisfactory. Note that the calculated response must meet both the ductility ratio and support rotation criteria.

SBEDS also calculates the maximum reaction at each support (V_u,L and V_u,R) and the shear capacity of the panel. As shown below, the maximum reaction does not exceed the shear capacity, as indicated by the message that "Shear is OK". *As noted at the bottom, the maximum reaction forces are assumed to be caused only by flexural response.* It is assumed that the user has previously considered the effect of tension membrane force on the supports in order to calculate the input support capacity for tension membrane in the component. Additional information for the calculated response histories is shown on the Results sheet.

Results Summary				
θ_{max} =	5.43 deg.	Design Criteria:	LLOP/Secondary-NS	
μ =	3.78	Response OK compared to input design criteria		
X_{max} Inbound =	95.06 mm	at time =	21.40 msec	
X_{min} Rebound =	0.00 mm	at time =	0.00 msec	
R_{max} =	11.75 kPa	at time =	21.40 msec	
R_{min} =	-8.40 kPa	at time =	45.50 msec	
Shortest Yield Line Distance to Determine θ:			1000.0 mm	
Equivalent Static Reactions*				
Peak Reactions Based on Ultimate Flexural Resistance: Vu				
V_uL =			10.50	N/mm
V_uR =			6.30	N/mm
Shear Capacity				
Shear Area: A_v=			0.30	mm^2/mm
Shear Capacity: V_s =			30	N/mm
Results based on Max Shear		Shear is OK		
* Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.				

Example 2A: One-Way or Two-Way Steel Plate (English)

Analyze the flexural response of a two-way steel plate for the effects of 50 lbs of TNT at 250 ft of standoff distance (Fully Reflected). The plate is 3/8 inches thick, and has a height and a width of 4 ft by 4 ft. The plate has fixed supports on two adjacent sides and is free (i.e., unsupported) on the other two sides. Specific information on the plate's material properties is known as shown below.

f_y = 40000 psi
E = 29000000 psi
SIF = 1.21
DIF = 1.10

Additionally, assume the plate is in the vertical position and does not support additional weight. Assume typical values for steel density and Poisson's ratio. The plate is required to meet HLOP and is considered a secondary type member.

Analysis Parameters:

- Two-way Member, L = 4 ft, H = 4 ft
- Thickness = 3/8 in.
- Fixed Supports on two adjacent sides, Free on other two sides
- No supported weight
- HLOP for secondary type component is required
- 50 lbs of TNT at 250 ft, fully reflected blast loading

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way and Two-Way Metal Plate" and English units, and click on the button to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) using the information given in the problem statement. For this particular problem:

- Set the Boundary Conditions to "Two-Way: Two Adj. Sides Supported – Both Fixed."
- Select "User Defined" from the material type drop down menu and click the user defined button to enter the material properties provided in the problem statement.
- Select "Charge weight and standoff" under Blast Load input type to activate the charge weight and standoff input box.
- In the Charge Weight and Standoff input box select "Reflected without Clearing" under Charge Weight Load Type and enter 0 for the Incidence Angle (or leave blank) to account for full blast load reflection off the plate.
- Select " None (vertical component)" under Gravity Displacement
- Set the Dynamic Axial Load input cell to "No Dynamic Axial Load"

Next, go to the Response Criteria box and select "All steel plates" and HLOP/Secondary-NS to set the allowable response limits. Finally, go to the Solution Control box and select a time step for the analysis. The time step should always be less or equal than the recommended value in SBEDS. After filling in the input cells, the input sheet will look as follows.

One-Way and Two-Way Metal Plate

User Info: Fill in Yellow Cells, See Note Below for White Cells		
Span Length, L:	4	ft
Span Width, H	4	ft
Boundary Conditions:	Two-Way: Two Adj. Sides Supported - Both Fixed	
Response Type:	Flexural	

Structural & Material Properties		
Plate Thickness, t:	0.375	in
Plate Density, ρ:	489	lb/ft^3
Poisson's Ratio, ν:	0.3	
Self-Weight, w:	15.3	psf
Supported Weight, W:	0	psf
Material Type:	User Defined	
Yield Strength, f_y:	40,000	psi
Elastic Modulus, E:	29000000	psi
Static Strength Increase Factor:	1.21	
Dynamic Increase Factor:	1.1	
Dynamic Yield Stress, f_{dy}:	53,240	psi
Leave Blank	0	

Click for User Defined Material

Calculated Properties		
Moment of Inertia, I:	0.00	in^4/in
Section Modulus, S:	0.02	in^3/in
Plastic Modulus, Z:	0.04	in^3/in
Moment Capacity:	1,560	lb-in/in

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

None (vertical component)

Pressure-Time Input	
Time	Pressure
(ms)	(psi)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff	
W	R
(lbs TNT)	(ft)
50	250
Blast Load Phase	
Positive phase only	
Charge Weight Load Type	
Reflected without Clearing	
Parameters for Reflected Loads	
Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	0

See notes under error messages

Load file name	
Applied Blast Input File Not Selected	
Response Criteria	
All steel plates	
LOP/Type	HLOP/Secondary-NS
θ (deg)	µ
1	4

See All COE Response Criteria

Dynamic Shear Factors		
Shear Constant	Elastic	Plastic
F (long side) =	0.23	0.17
R (long side) =	0.25	0.32
F (short side) =	0.23	0.17
R (short side) =	0.25	0.32

Solution Control		
Inbound Natural Period:	101.27	ms
Rebound Natural Period:	101.27	ms
Max Recommended Time Step:	0.28	ms
Time Step:	0.28	ms
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties			
Property	Inbound	Rebound	Units
Mass, M	274.6	274.6	psi-ms^2/in
Load-Mass Factors, K_{LM}			
K_{LM1}	0.65	0.65	
K_{LM2}	0.65	0.65	
K_{LM3}	0.50	0.50	
Stiffness, K			
K_1	0.69	0.69	psi/in
K_2	0.17	0.17	psi/in
K_3	0.00	0.00	psi/in
Resistance, R			
R_1	4.39	-4.39	psi
R_2	7.31	-7.31	psi
Yield Displacement, x			
x1	6.38	-6.38	in
x2	23.65	-23.65	in
Equiv Yield Defl., X_E	15.84	-15.84	in

After the input sheet is completed as shown in the above figure, click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the plate. As shown in the Results Summary shown below, the calculated maximum dynamic displacement of the plate is 0.75 inches, which corresponds to a ductility ratio of 0.05 and a support rotation of 0.90 degrees. Therefore, the response compares favorably with the response criteria for the selected LOP for this analysis. Note that the calculated response must meet both the ductility ratio and support rotation criteria. The Results Summary box also displays the calculated shear capacity and the peak shear reactions in both directions. For this case the shear capacity of the plate is enough to resist the calculated demand, which is based on the ultimate flexural response of the plate. For more information on how to calculate shear reactions please refer to the SBEDS User's Methodology Manual that is distributed with SBEDS.

Results Summary					
θ_{max} =	0.90	deg.	Design Criteria:	HLOP/Secondary-NS	
μ =	0.05		Response OK compared to input design criteria		
X_{max} Inbound =	0.75	in	at time =	30.52	msec
X_{min} Rebound =	-0.75	in	at time =	81.20	msec
R_{max} =	0.52	psi	at time =	30.52	msec
R_{min} =	-0.52	psi	at time =	81.20	msec
Shortest Yield Line Distance to Determine θ:				48.0	in
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
Vu at supports in L direction				211	lb/in
Vu at supports in H direction				211	lb/in
Shear Capacity					
Shear Capacity: V_s =				10,981	lb/in
Results based on Max Shear Region				Shear is OK	

* Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.

Example 2B: One-Way or Two-Way Aluminum Plate (Metric)

Analyze the flexural response of a plate of 6061 T6 aluminum. The plate has simple supports on all four sides and is required to provide MLOP as a secondary type component. The plate is 40 meters away from a TNT charge of 5 kg. Include positive and negative blast phase for the analysis. Often only positive phase blast load is used for blast resistant design, which is usually a conservative approach, but negative phase blast load can be included and is often included when analyzing existing components. In the case of existing components, a more accurate damage assessment is usually desirable due to cost and construction issues that are typically involved in upgrading components against blast loads. The plate has a thickness of 9.5 mm and clear span dimensions of 1m x 1m. Assume the plate is in the vertical position and does not support additional weight. Use typical values for aluminum density and Poisson's ratio. Use 1% of critical damping.

Analysis Parameters:
- Two-way Member, L = 1 m, H = 1 m
- 6061 T6 aluminum
- Thickness = 9.5 mm.
- Simple supports all sides
- No supported weight
- 1 % critical damping
- MLOP for secondary type component is required
- 5 kg of TNT at 40 m. Positive and negative phase

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way and Two-Way Metal Plate" and metric units, and click on the button to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) using the information given in the problem statement. For this particular problem:

- Set the Boundary Conditions to "Two-Way: Four Sides Supported – All Simple."
- Use the material type drop down menu to select the aluminum type 6061 T6.
- Select "Charge weight and standoff" under Blast Load input type to enable the charge weight and standoff input box
- Select " None (vertical component)" under Gravity Displacement
- In the charge weight and standoff input box, select "Positive and negative", under Blast Load Phase.
- In the charge weight and standoff input box, select "Reflected without Clearing" under Charge Weight Load Type and enter a zero Incidence Angle for full blast load reflection.
- Set the Dynamic Axial Load input cell to "No Dynamic Axial Load"

On the Response Criteria input box, select "All steel plates" and "MLOP/Secondary-NS". (No PDC response criteria have been developed specifically for aluminum plates at this time and therefore the steel plates category is selected for this example. The user must determine if the use of the steel response limits is appropriate for their analysis.) Finally, enter 1 for "% of Critical Damping" in the the Solution Control input box and choose a time step equal or smaller than the recommended value in SBEDS. After these steps, the input sheet will look as follows.

One-Way and Two-Way Metal Plate

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

Span Length, L:	1000	mm
Span Width, H	1000	mm
Boundary Conditions:	Two-Way Four Sides Supported - All Simple	
Response Type:	Flexural	

Structural & Material Properties

Plate Thickness, t:	9.5	mm
Plate Density, ρ:	2700	kg/m³
Poisson's Ratio, ν:	0	
Self-Weight, w:	25.7	kg/m²
Supported Weight, W:	0	kg/m²
Steel Type:	6061 T6 Aluminum	
Yield Strength, f_y:	241	MPa
Elastic Modulus, E:	68,948	MPa
Static Strength Increase Factor	1.07	
Dynamic Increase Factor:	1.02	
Dynamic Yield Stress, f_{dy}:	263	MPa
Leave Blank	0	

Click for User Defined Material

Calculated Properties

Moment of Inertia, I:	71.4	mm⁴/mm
Section Modulus, S:	15.0	mm³/mm
Plastic Modulus, Z:	22.6	mm³/mm
Moment Capacity:	4952	N-mm/mm

See All COE Response Criteria

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (kPa)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (kg TNT)	R (m)
5	40

Blast Load Phase: Positive and negative phase

Charge Weight Load Type: Reflected without Clearing

Parameters for Reflected Loads

Wall Height (m)¹	
Wall Width (m)¹	
Incidence Angle	0

See notes under error messages

Load file name

Applied Blast Input File Not Selected

Response Criteria

All steel plates

LOP/Type: MLOP/Secondary-NS

θ (deg)	μ
2	8

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (long side) =	0.07	0.09
R (long side) =	0.18	0.16
F (short side) =	0.07	0.09
R (short side) =	0.18	0.16

R (short side) =

Solution Control

Inbound Natural Period:	22.92	ms
Rebound Natural Period:	22.92	ms
Max Recommended Time Step:	0.06	ms
Time Step:	0.27	ms
% of Critical Damping:	1	%
Initial Velocity:	0	mm/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	25.7	25.7	kg/m²
Load-Mass Factors, K'LM			
K_{LM1}	0.63	0.63	
K_{LM2}	0.63	0.63	
K_{LM3}	0.50	0.50	
Stiffness, K			
K_1	1.21	1.21	kPa/mm
K_2	1.21	1.21	kPa/mm
K_3	0.00	0.00	kPa/mm
Resistance, R			
R_1	105.21	-105.21	kPa
R_2	105.21	-105.21	kPa
Yield Displacement, x			
x1	86.66	-86.66	mm
x2	86.66	-86.66	mm
Equiv Yield Defl, X'E	86.66	-86.66	mm

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the plate. As shown in the Results Summary shown below, the calculated maximum dynamic displacement of the plate is 11.54 mm (in rebound), which corresponds to a ductility ratio of 0.13 and a support rotation of 1.32 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Note that the calculated response must meet both the ductility ratio and support rotation criteria.

SBEDS also calculates the maximum reaction along the sides of the plate and the shear capacity of the plate. For this case, the maximum reactions do not exceed the shear capacity, as indicated by the message that "Shear is OK". As noted at the bottom, the maximum reaction forces are assumed to be caused only by flexural response. Additional information for the calculated response histories is shown on the Results sheet.

Results Summary					
θ_{max} =	-1.32 deg.	Design Criteria:	MLOP/Secondary-NS		
μ =	0.13 (Rebound)	Response OK compared to input design criteria			
X_{max} Inbound =	8.27	mm	at time =	33.48	msec
X_{min} Rebound =	-11.54	mm	at time =	21.06	msec
R_{max} =	10.04	kPa	at time =	33.48	msec
R_{min} =	-14.01	kPa	at time =	21.06	msec
Shortest Yield Line Distance to Determine θ:				500.0	mm
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
Vu at supports in L direction				31.35	N/mm
Vu at supports in H direction				31.82	N/mm
Shear Capacity					
Shear Capacity: V_s =				1,376	N/mm
Results based on Max Shear Region				Shear is OK	

* Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.

Example 3A: One-Way Open-Web Steel Joist (English)

In this example we will take advantage of the option to apply a blast load to a roof joist using the dynamic reaction time history of the roof deck. This may provide a more accurate, although less conservative, analysis of the joist's response. The dynamic reaction time history calculated for the corrugated panel in Example 1A will be used to analyze the flexural response of an open-web roof joist. The joists are type 12 K1, with a 25 ft span and are spaced at 5 ft O.C. The roof joists are required to provide MLOP and are considered secondary type components.

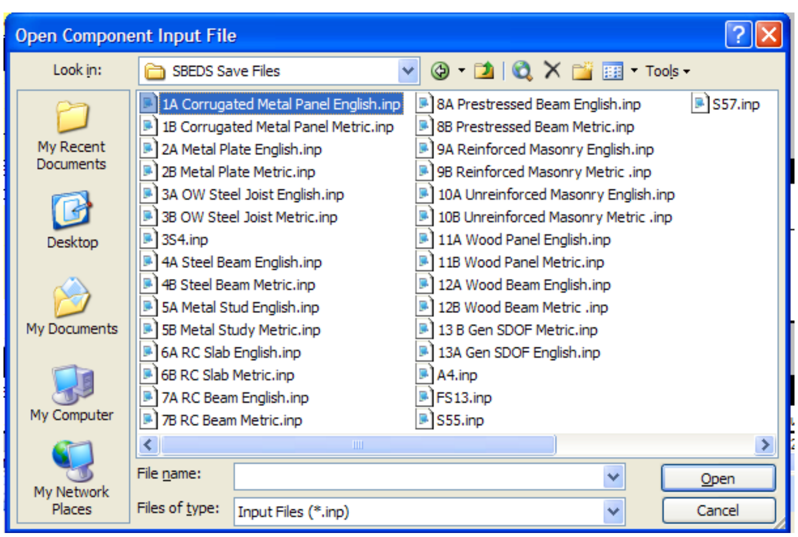
Analysis Parameters:

- Span length of 25 ft
- Joist spacing of 5 ft
- Joist size of 12 K1
- MLOP for joist acting as a secondary type component
- Dynamic reaction pressure load from corrugated panel in Example Problem 1A
- Supported weight of roofing material and metal panels equal to 3 psf

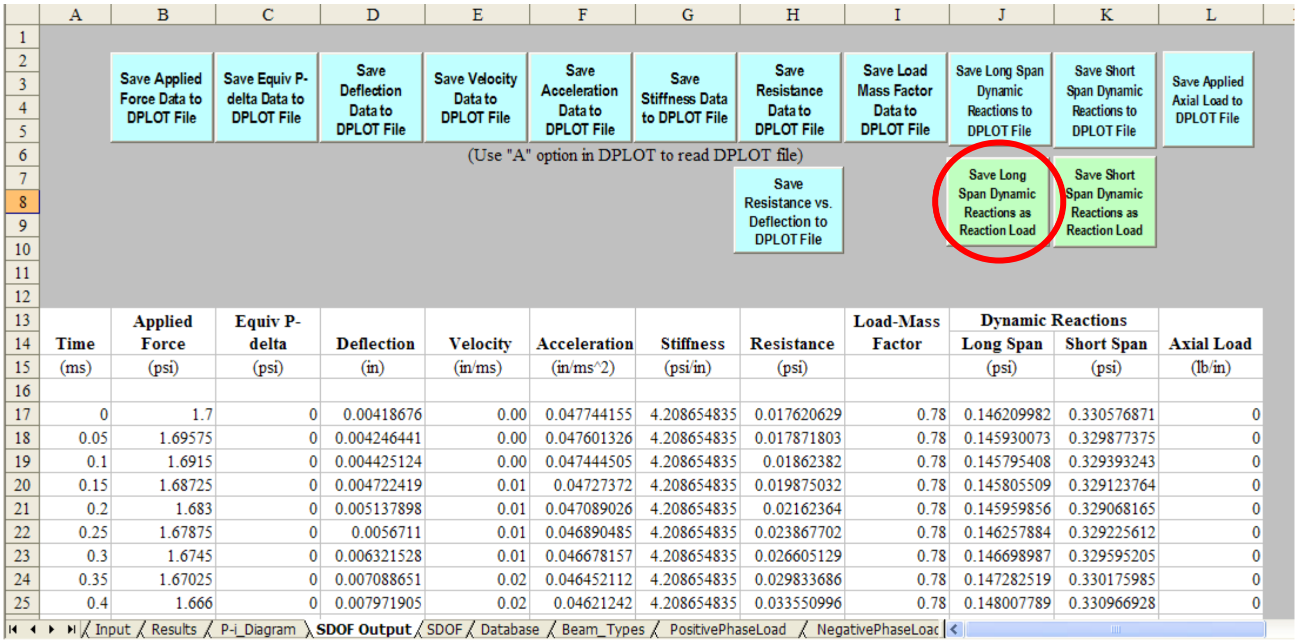
Solution

On the "Intro" worksheet area (Figure 1), select "Open-Web Steel Joist" and English units and click the button near the bottom of the page to initiate the open-web steel joists input sheet. On the input sheet, fill in the input cells (in yellow) using the information provided in the problem statement.

The file with the dynamic reaction pressure from Example 1A can be created at the end of the analysis of that component, as explained in Example Problem 1A. However, we will assume that was not done in order to also demonstrate the Retrieve file capability in SBEDS. First, save the input file for the current example using the "Save" button to a file on the computer hard drive (so any current input for this example problem is not lost), then click on the "Retrieve" button at top of the screen (Figure 2), to open 1A Corrugated Metal Panel English.inp. After you click on the "Retrieve" button a window as shown below will open prompting you to select the file you would like to open. Select Example 1A (or the name you assigned to that example) and click open.

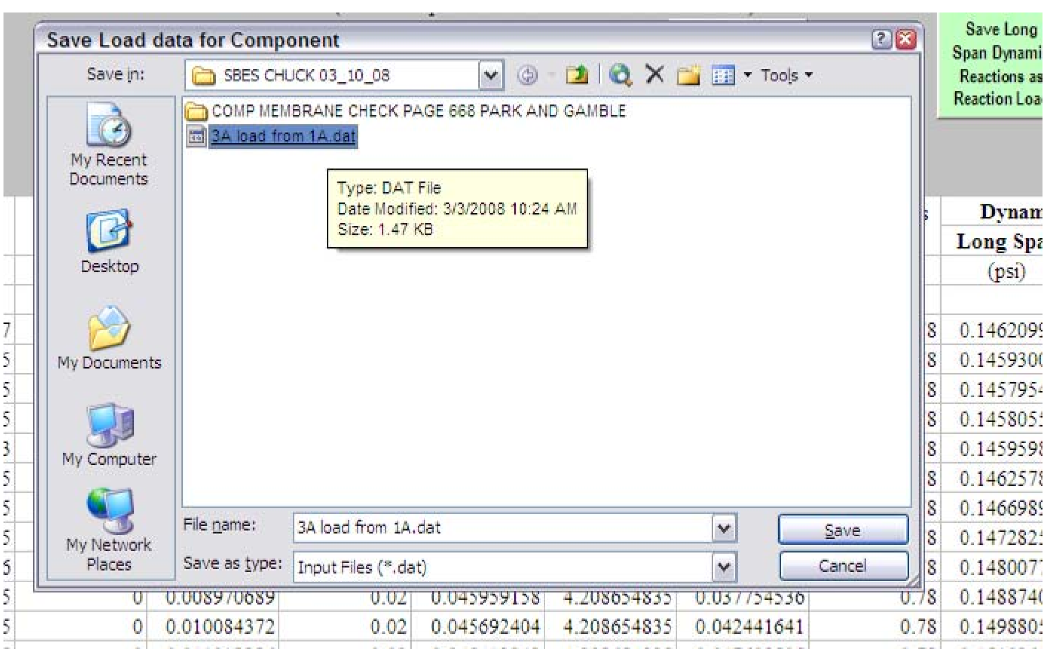


After you open Example 1A, the input screen will show. Click “RUN SDOF” to run the analysis. After you run the analysis go to the “SDOF Output” sheet and click on the “Save Short Span Dynamic Reaction as Reaction Load” button on the top right of the screen (circled in red below).

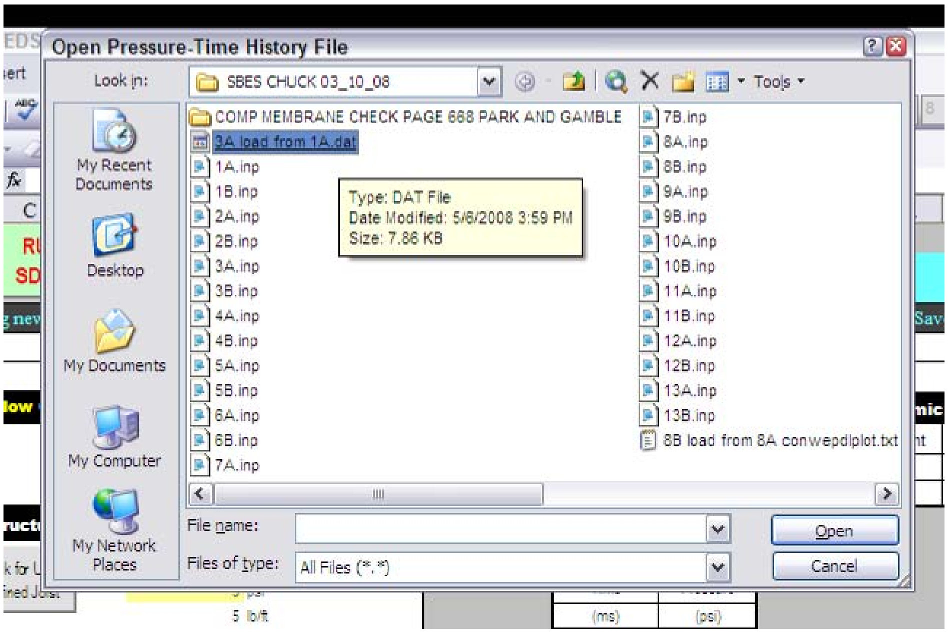


Time (ms)	Applied Force (psi)	Equiv P-delta (psi)	Deflection (in)	Velocity (in/ms)	Acceleration (in/ms^2)	Stiffness (psi/in)	Resistance (psi)	Load-Mass Factor	Dynamic Reactions Long Span (psi)	Dynamic Reactions Short Span (psi)	Axial Load (lb/in)
0	1.7	0	0.00418676	0.00	0.047744155	4.208654835	0.017620629	0.78	0.146209982	0.330576871	0
0.05	1.69575	0	0.004246441	0.00	0.047601326	4.208654835	0.017871803	0.78	0.145930073	0.329877375	0
0.1	1.6915	0	0.004425124	0.00	0.047444505	4.208654835	0.01862382	0.78	0.145795408	0.329393243	0
0.15	1.68725	0	0.004722419	0.01	0.04727372	4.208654835	0.019875032	0.78	0.145805509	0.329123764	0
0.2	1.683	0	0.005137898	0.01	0.047089026	4.208654835	0.02162364	0.78	0.145959856	0.329068165	0
0.25	1.67875	0	0.0056711	0.01	0.046890485	4.208654835	0.023867702	0.78	0.146257884	0.329225612	0
0.3	1.6745	0	0.006321528	0.01	0.046678157	4.208654835	0.026605129	0.78	0.146698987	0.329595205	0
0.35	1.67025	0	0.007088651	0.02	0.046452112	4.208654835	0.029833686	0.78	0.147282519	0.330175985	0
0.4	1.666	0	0.007971905	0.02	0.04621242	4.208654835	0.033550996	0.78	0.148007789	0.330966928	0

A new window will come up prompting you to save the dynamic reaction as a .dat file. You need to select the folder in which you wish to save the file and the file name. For this example, we have name the file “ 3A load from 1A.dat” and saved it in the same directory. This is illustrated next.



After you save the dynamic reaction file, return to the input sheet and retrieve the file for Example 3A. The input sheet for Example 3A appears "Open-Web Steel Joist". Under Blast Load Input Type select "Pressure-time history file." A new window opens and prompts you select the file you wish you use as the pressure-time history load for this analysis. Select the file created in the previous step.



After the file is selected, SBEDS reads the values into the analysis and is ready to perform the analysis. Enter the desired LOP and time step. Also enter the Gravity Displacement as in the direction of blast load. This input is typically applicable for roof components subject to exterior blast load. Your final input screen will look as follows. Notice that, the "Pressure-Time input" box and the "Charge weight and Standoff" input box are both disabled.

Open-Web Steel Joist

User Info: Fill in Yellow Cells, See Note Below for White Cells	
Span, L:	25 ft
Joist Spacing, B:	5 ft
Loading Condition:	Simple-Simple, Uniformly Loaded

Structural & Material Properties	
Joist Designation: (Click for User Defined Joist)	12K1
Supported Weight, W:	3 psf
Self-Weight, w:	5 lb/ft
Allowable Joist Design Load, w_{design}:	155 lb/ft
Load causing L/360 defl., w_{LL}:	73 lb/ft

Blast Load Input Type
Pressure-time history file
Gravity Displacement
In direction of blast load

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

Pressure-Time Input	
Time	Pressure
(ms)	(psi)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Solution Control	
Inbound Natural Period:	134.60 ms
Rebound Natural Period:	134.60 ms
Max Recommended Time Step:	0.01 ms
Time Step:	0.01 ms
% of Critical Damping:	0 %
Initial Velocity:	0 in/ms

Charge Weight and Standoff	
W	R
(lbs TNT)	(ft)
Blast Load Phase	
Positive phase only	
Charge Weight Load Type	
Reflected with Clearing	
Parameters for Reflected Loads	
Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	

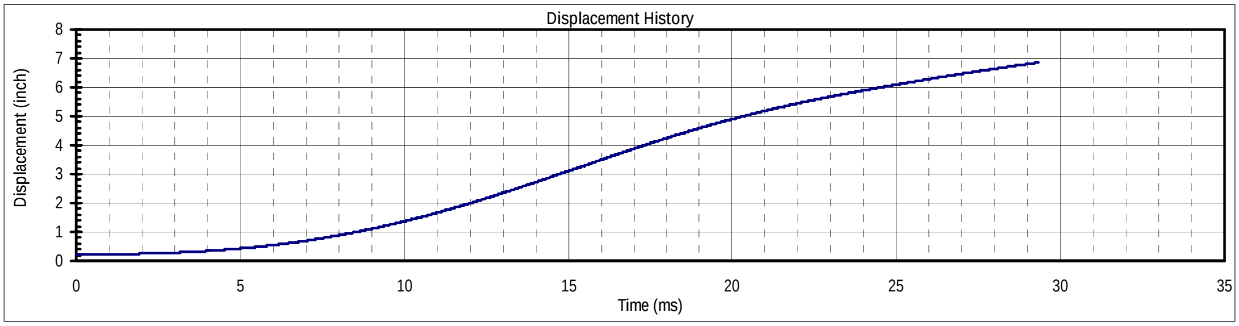
See notes under error messages

SDOF Properties			
Property	Inbound	Rebound	Units
Mass, M	71.9	71.9	psi-ms²/in
Load-Mass Factors, K_{LM}			
Elastic	0.78	0.78	
Elastic-Plastic	0.78	0.78	
Plastic	0.66	0.66	
Stiffness, K			
Elastic	0.12	0.122	psi/in
Elastic-Plastic	0.00	0.000	psi/in
Effective	0.12	0.122	psi/in
Resistance, R			
Elastic	0.46	-0.46	psi
Plastic	0.46	-0.46	psi
Equiv Yield Defl., X_E	3.74	3.74	in

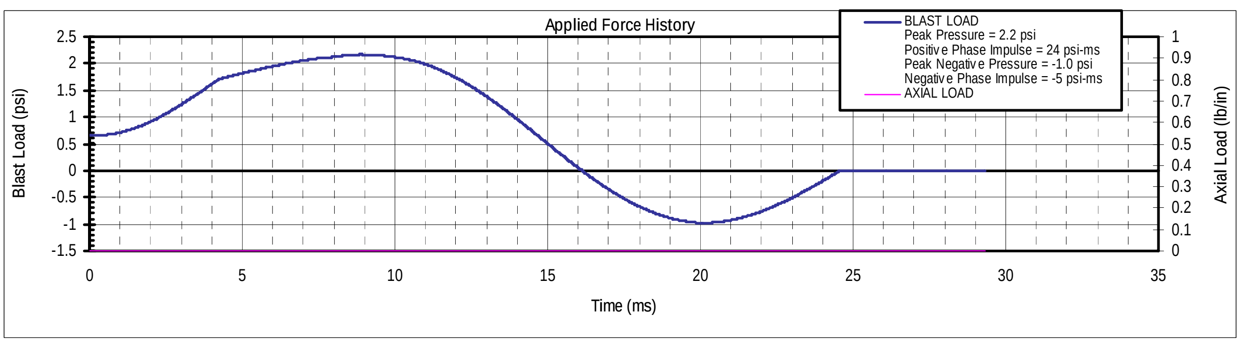
Load file name	
3A load from 1A.dat	
Response Criteria	
Downward flexural response	
LOP/Type	MLOP/Secondary-NS
θ (deg)	µ
3	N/A

See All COE Response Criteria

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the plate. In this case, SBEDS gives a warning message that maximum response was not reached. On the Results sheet, the calculated Displacement vs. Time relationship is as shown below, clearly indicating that the SDOF analysis did not calculate the actual component maximum deflection. The calculation is therefore unconservative and a longer time step is required.



The applied blast force (i.e., pressure) history, which is also on the Results sheet, is shown below. This is a relatively smooth function, such that a time step of 0.03 ms is clearly sufficient to capture the shape very accurately, as opposed to the more conservative value of 0.01 ms recommended in SBEDS. Also, the Input sheet above shows that the natural period of the joist is 134 ms. A time step no greater than 10% of this value is generally needed to model the component response in the time-stepping SDOF solution used in SBEDS. The time step of 0.03 ms will clearly meet these criteria. Therefore, rerun SBEDS with an input time step of 0.03 ms. This will increase the calculated response time for the component by a factor of 3 and will capture the maximum component deflection, which is a necessary part of a SDOF analysis.



As shown in the Results Summary below, the calculated maximum dynamic displacement of joist is 8.21 inches. This corresponds to a ductility ratio of 2.2 and a support rotation of 3.13 degrees. The calculated response exceeds the allowable limit by less than 5%. In many cases, it is acceptable for the response to exceed the limit value by a very small amount.

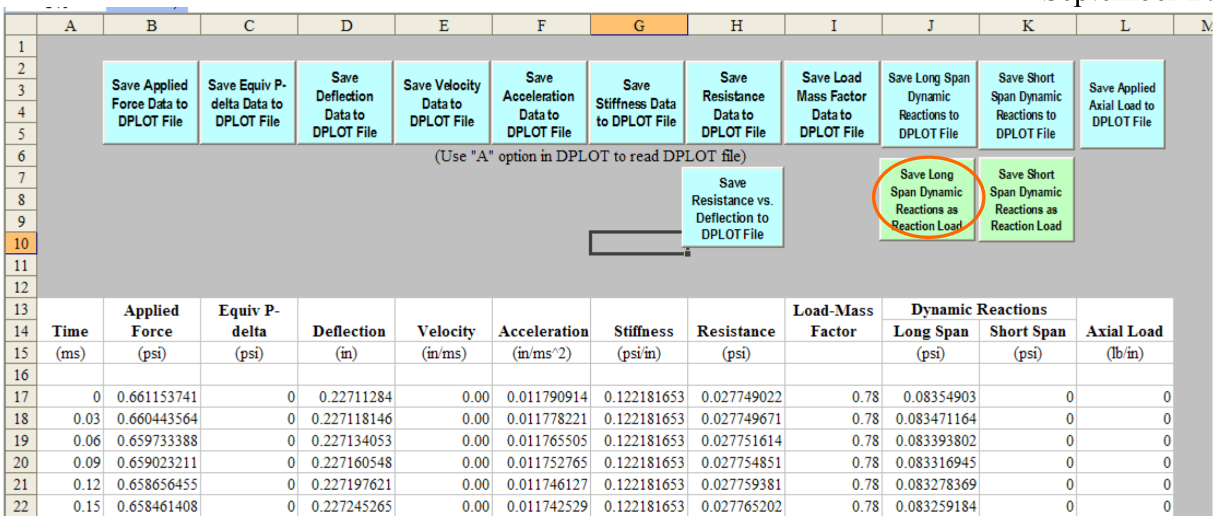
An identical SBEDS analysis except the blast load from Example 1A was input, rather than the corresponding dynamic reaction history, calculated a maximum deflection of 7.1 inches. However, this is not necessarily representative of the difference in comparable SDOF analyses using the directly applied blast load and the dynamic reaction load from a supported component. Other comparisons have shown a lower calculated maximum deflection for the case of the dynamic reaction load. There is no well accepted guidance on when a directly applied blast load should be used and when a dynamic reaction load should be used. Both approaches are generally considered acceptable for design of framing components that support a blast-loaded component.

Results Summary					
θ_{max} =	3.13 deg.	Design Criteria:	MLOP/Secondary-NS		
μ =	2.20	Response NOT OK compared to input design criteria			
X_{max} Inbound =	8.21 in		at time =	46.65 msec	
X_{min} Rebound =	0.00 in		at time =	0.00 msec	
R_{max} =	0.46 psi		at time =	46.65 msec	
R_{min} =	-0.12 psi		at time =	87.90 msec	
Shortest Yield Line Distance to Determine θ:				150.0 in	
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
V_uL =				4,110 lb	
V_uR =				4,110 lb	
* Based on larger of inbound and rebound ultimate flexural resistance.					

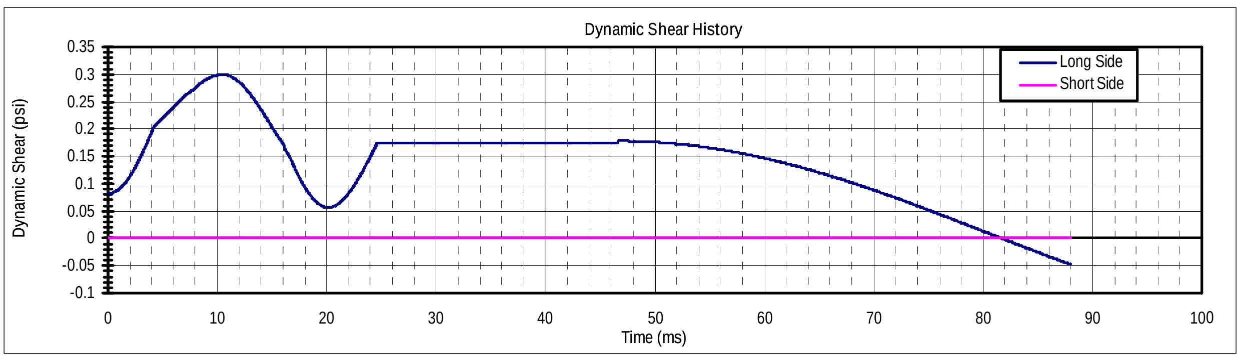
SBEDS also calculates the maximum reaction at both ends of the joists, which are based on the ultimate flexural capacity of the joist and are commonly used to design the connections of the joist to the supporting member.

In Example Problem 5A, it will be assumed that these joists are supported by a load bearing metal stud wall. The dynamic reaction pressure from the joists causes a dynamic axial load on the load bearing wall, which causes a dynamic P-delta moment in the loading bearing wall as it deflects laterally from applied blast load. This dynamic axial load can be read into the SBEDS analysis of the load bearing wall based on a save file for the dynamic pressure history from the joists.

Create a Save file from the joist analysis by going to the “SDOF Output” sheet in the same manner already described at the beginning of this example for the dynamic reaction pressure history of the corrugated metal panel supported by the joist. A saved dynamic reaction pressure history can be read into SBEDS as either an applied blast load, or as a dynamic axial load. In the latter case, SBEDS will use information on the span of the saved component, which is also in the save file, to convert the dynamic reaction pressure into an axial line load on the analyzed component. This is explained in more detail in the SBEDS Help document. For demonstration purposes, the same saved dynamic reaction pressure history file can be read into SBEDS as both an applied blast load and a dynamic axial load. In this case, the green save file button circled below is used to save the joist dynamic reaction pressure history to a file on the hard drive. The dynamic reaction history (also referred to as the dynamic shear history) is also plotted in SBEDS at the bottom of the Results sheet as shown below.



Time (ms)	Applied Force (psi)	Equiv P-delta (psi)	Deflection (in)	Velocity (in/ms)	Acceleration (in/ms^2)	Stiffness (psi/in)	Resistance (psi)	Load-Mass Factor	Dynamic Reactions Long Span (psi)	Dynamic Reactions Short Span (psi)	Axial Load (lb/in)
0	0.661153741	0	0.22711284	0.00	0.011790914	0.122181653	0.027749022	0.78	0.08354903	0	0
0.03	0.660443564	0	0.227118146	0.00	0.011778221	0.122181653	0.027749671	0.78	0.083471164	0	0
0.06	0.659733388	0	0.227134053	0.00	0.011765505	0.122181653	0.027751614	0.78	0.083393802	0	0
0.09	0.659023211	0	0.227160548	0.00	0.011752765	0.122181653	0.027754851	0.78	0.083316945	0	0
0.12	0.658656455	0	0.227197621	0.00	0.011746127	0.122181653	0.027759381	0.78	0.083278369	0	0
0.15	0.658461408	0	0.227245265	0.00	0.011742529	0.122181653	0.027765202	0.78	0.083259184	0	0



The save file is shown below. It has the format of dynamic reaction pressure, time. The dynamic reaction pressures are automatically multiplied by a factor of 2 by SBEDS before they are saved in the save file, except for cantilevered components, as explained in Chapter 3 of the SBEDS Methodology Manual. The last line of the save file has the format *-999, Ls*, *explanatory text* where Ls is the tributary span length of the supported component that is used to convert the dynamic reaction pressures in the save file at each time step to the corresponding dynamic reaction loads at the support along the loaded width of the component. This conversion only occurs in SBEDS when a saved dynamic reaction pressure is read into SBEDS as the dynamic axial load on another analyzed component. In this case, Ls = 150 inches. The save files also has some explanatory text, which is essentially a definition of Ls.

0,0.167098060443984
0.06,0.166787604280721
0.12,0.166556737119352
0.18,0.16648100499747
0.24,0.166559273290554
0.3,0.166716557049734
0.36,0.167100870627656
0.42,0.167562817340973
0.48,0.168175999764054
0.54,0.168938777676039
0.6,0.169778408474853
0.66,0.170837699064522
0.72,0.171971981201682
0.78,0.173252136088858

…..

87.5400000000026,-8.91218641567195E-02
87.6000000000026,-9.00045593568374E-02
87.6600000000026,-9.08863762811055E-02
87.7200000000026,-9.17673080147712E-02
87.7800000000026,-9.26473476500448E-02
87.8400000000026,-9.35264882861538E-02
87.9000000000026,-9.44047230293969E-02
87.9600000000026,-9.52820449931985E-02
-999,150, Tributary span length of component applying axial pressure…

Example 3B: One-Way Open-Web Steel Joist (Metric)

Analyze the response of a 24LH04 roof joist that is part of a roof system that is being designed to resist the effects of 200 kg of TNT at 70 m of standoff distance. The charge is placed so that only the side-on pressure loads the roof. The joists in the roof system are 6.5 m long and are spaced at 6 m on center. Assume the joist's supported weight is 10 kg/m^2. Check that the flexural response of the joist will provide a LLOP as a secondary type component.

Analysis Parameters:

- Span length L= 6.5 m
- Joist spacing B= 6 m
- Joist size of 24LH04
- LLOP for joist acting as a secondary type component
- 200 kg of TNT at 70 m. Side-on pressure only
- Supported weight of roofing material 10 kg/m^2

Solution

On the "Intro" worksheet area (Figure 1), select "Open-Web Steel Joist" and Metric units and click the button near the bottom of the page to initiate the open-web steel joists input sheet. On the input sheet, fill in the input cells (in yellow) using the information provided in the problem statement. For this particular problem:

- Select "24LH04" using the drop down menu for Joist Designation in the Structural & Material Properties input box.
- Also, in the Structural & Material Properties input box, enter 10 kg/m^2 for supported weight.
- On the Blast Load Input Type box, select "Charge weight and standoff"
- Set the Gravity Displacement input cell to "In direction of blast load"
- On the Charge Weight and Standoff input box, enter 200 kg of TNT and 70 m of standoff distance. Use only positive phase in this case for design and set the Charge weight load type to "Side-on."
- Set the Dynamic Axial Load input cell to "No Dynamic Axial Load"

On the Response Criteria input box, select "Downward Flexure" and LLOP/Secondary-NS. Finally go to the Solution Control input box and select a time step equal or less than the maximum recommended value in SBEDS. Enter 0 for % of critical damping and initial velocity. The input sheet will look as follows.

Open-Web Steel Joist

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

Span, L:	6500	mm
Joist Spacing, B:	6000	mm
Loading Condition:	Simple-Simple, Uniformly Loaded	

Structural & Material Properties

Joist Designation:	24LH04	
Supported Weight, W:	10	kg/m^2
Self-Weight, w:	17.85	kg/m
Allowable Joist Design Load, w_{design}:	9.65	KN/m
Load causing L/360 defl., w_{LL}:	16.27	KN/m

Click for User Defined Joist

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

In direction of blast load

Dynamic Shear Factors

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

Pressure-Time Input

Time (ms)	Pressure (kPa)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Solution Control

Inbound Natural Period:	51.58	ms
Rebound Natural Period:	51.58	ms
Max Recommended Time Step:	0.14	ms
Time Step:	0.14	ms
% of Critical Damping:	0	%
Initial Velocity:	0	mm/ms

Charge Weight and Standoff

W (kg TNT)	R (m)
200	70

Blast Load Phase: Positive phase only

Charge Weight Load Type: Side-on

Parameters for Reflected Loads

Wall Height (m)[1]	
Wall Width (m)[1]	
Incidence Angle[2]	

See notes under error messages

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	12.98	12.98	kg/m^2
Load-Mass Factors, K_{LM}			
Elastic	0.78	0.78	
Elastic-Plastic	0.78	0.78	
Plastic	0.66	0.66	
Stiffness, K			
Elastic	0.15	0.150	kPa/mm
Elastic-Plastic	0.00	0.000	kPa/mm
Effective	0.15	0.150	kPa/mm
Resistance, R			
Elastic	3.42	-3.42	kPa
Plastic	3.42	-3.42	kPa
Equiv Yield Defl., X_E	22.74	22.74	mm

Load file name

Applied Blast Input File Not Selected

Response Criteria

Downward flexural response

LOP/Type: LLOP/Secondary-NS

θ (deg)	μ
6	N/A

See All COE Response Criteria

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the joist. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box shown below. For this problem, the calculated maximum dynamic displacement of the joist is 272.16 mm. This corresponds to a ductility ratio of 11.97 and a support rotation of 4.79 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Note that the calculated response must meet only the support rotation criteria since there is no ductility limitation for this component at this level of protection.

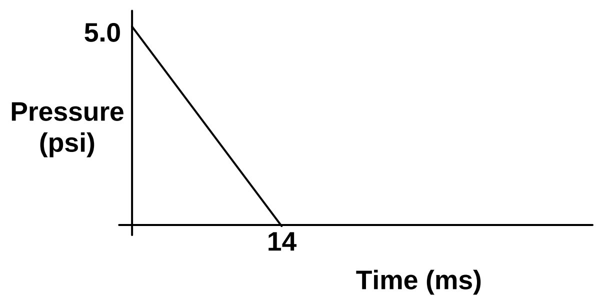
SBEDS also calculates the maximum reaction at both ends of the joists, which are based on the ultimate flexural capacity of the joist and are commonly use to design the connections of the joist to the supporting member

Results Summary					
θ_{max} =	4.79 deg.	Design Criteria:	LLOP/Secondary-NS		
μ =	11.97	Response OK compared to input design criteria			
X_{max} Inbound =	272.16 mm	at time =	47.60 msec		
X_{min} Rebound =	0.85 mm	at time =	0.00 msec		
R_{max} =	3.42 kPa	at time =	47.60 msec		
R_{min} =	-3.16 kPa	at time =	73.36 msec		
Shortest Yield Line Distance to Determine θ:			3250.0 mm		
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
Vu,L =			66,593 N		
Vu,R =			66,593 N		

* Based on larger of inbound and rebound ultimate flexural resistance.

Example 4A: One-Way Steel Beam or Beam Column (English)

Analyze the flexural response of a user-defined cold-formed roof purlin subject to a blast load as defined below.



The purlin has the following non-typical cross section and material properties. The static and dynamic increase factors are recommended values for cold-formed steel members in TM 5-1300 and the SBEDS Methodology Manual.

- Self weight = 4.5 lb/ft
- Moment of Inertia = 12.0 in^4
- Section Modulus = 3.2 in^3
- Web thickness = 0.07 in
- Depth = 8.0 in
- Area = 1.30 in^2
- Yield strength = 45,000 psi
- Ultimate strength = 75,000 psi
- Elastic Modulus = 29,000,000 psi
- Static Strength Increase Factor = 1.1
- Dynamic Increase Factor = 1.21

The purlins are 25 ft long and are spaced at 5 ft on center. They are continuously supported along the compression flange by cold-formed roof panels. The bottom flange is braced with rods for rebound at 7.5 ft spacing. Include the effects of tension membrane in your analysis, assuming a connection capacity of 12 kips. The purlins support 3 psf of roof materials and panels and must provide LLOP for secondary type components.

Analysis Parameters:

- Span length L = 25 ft
- Purlin spacing B = 5 ft
- Material and cross section properties as specified above
- LLOP for a secondary type component
- The purlin connections and supports can resist 12 kips of tension in purlin
- Purlin supports 3 psf of roofing panels and material

Solution
On the “Intro” worksheet area (Figure 1), select “One-Way Steel Beam or Beam Column” and English units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) using the information provided in the problem statement. For this particular problem:

- Set the Response Type to “ Flexural and Tension Membrane”
- On the Structural & Material Properties input box select and shape type (Cold Formed Section can be selected but it does not matter), and “User Defined” for shape size. After selecting “User Defined” click on the “Define user shape” button on the left and enter the section properties given above.
- Enter the supported weight of 3 psf and enter 0 ft for the inbound and 7.5 ft for the rebound Unbraced Lengths for the Compression Flange.
- Select “User Defined” from the drop down menu for Type and click on the “Define User Material” button to the left to enter the material properties provided in the problem statement.
- Enter 12,000 lb for Support Capacity for Tension Membrane, V_c.
- Go to the drop down menu under Blast Load Input Type to set it to “Manual Input”
- Set Gravity Displacement to “None (vertical component)” using the drop down menu.
- Enter the appropriate values of pressure and time in the Pressure-Time input box.
- Set the Response Criteria to “Cold-formed girts & purlins” and LLOP/Secondary-NS
- Set the Dynamic Axial Load input cell to “No Dynamic Axial Load”

Finally, on the “Solution Control” input box select a time step value equal or less than the recommended value and enter 0 for % of Critical Damping and Initial Velocity.

After the input is completed, the input screen will appear as shown on the next page.

One-Way Steel Beam or Beam-Column

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

Span, L:	25	ft
Spacing, B:	5	ft
Boundary Conditions:	Fixed-Simple, Uniformly Loaded	
Response Type:	Flexural and Tension Membrane	

Structural & Material Properties

Axis of Bending:	Strong (X-X)	
Shape Type:	Cold-Formed Sections (C, Z)	
Shape Size:	User Defined	
Self-Weight, w:	4.50	lb/ft
Moment of Inertia, I:	12.00	in^4
Section Modulus: Z (hot-rolled beam) or S (cold-formed beam):	3.20	in^3
Web Thickness, tw:	8.00	in
Depth, d:	0.07	in
Area, A:	1.30	in^2
Supported Weight, W:	3	psf
Loaded Area Factor - Enter 1.0 for Uniform Load	1	
Inbound Unbraced Length for Compression Flange, L_{bi}:	0	ft (0 for fully braced)
Rebound Unbraced Length for Compression Flange, L_{br}:	7.5	ft (0 for fully braced)
Material Type:	User Defined	
Yield Strength, f_y:	45,000	psi
Ultimate Strength, f_u:	75,000	psi
Elastic Modulus, E:	29000000	psi
Static Strength Increase Factor:	1.1	
Dynamic Increase Factor:	1.21	
Dynamic Yield Stress, f_{dy}:	59,895	psi
No Dynamic Axial Load		
[4] Static Axial Load, P:	0	lb
Leave blank for No Dynamic Axial Load		ft
Support Capacity for Tension Membrane, Vc:	12000	lb

Click to Define User Shape | Save User Defined Shape | Retrieve User Defined Shape | Click to Define User Material | Save User Defined Material | Retrieve User Defined Material

Calculated Properties

Inbound Moment Capacity, M_i:	191,664	lb-in
Rebound Moment Capacity, M_r:	169,875	lb-in
Rebound/Inbound Moment Capacity Ratio, MR:	0.89	
Not Used for Tension Membrane		

Blast Load Input Type

Manual input

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (psi)
0	5
14	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (lbs TNT)	R (ft)

Blast Load Phase: Positive phase only

Charge Weight Load Type: Side-on

Parameters for Reflected Loads

Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Applied Blast Input File Not Selected

Response Criteria

Cold-formed girts & purlins

LOP/Type: LLOP/Secondary-NS

θ (deg)	µ
10	N/A

Shear Flag[5]

See All COE Response Criteria

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (simple support) =	0.08	0.12
R (simple support) =	0.29	0.30
F (fixed support) =	0.19	0.12
R (fixed support) =	0.43	0.46

Solution Control

Inbound Natural Period:	137.26	ms
Rebound Natural Period:	137.26	ms
Max Recommended Time Step:	0.38	ms
Time Step:	0.21	ms
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	70.1	70.1	psi-ms²/in
Load-Mass Factors, K_{LM}			
K_{LM1}	0.78	0.78	
K_{LM2}	0.66	0.66	
K_{LM3}	0.66	0.66	
Stiffness, K			
K_1	0.11	0.11	psi/in
K_2	0.00	0.00	psi/in
K_3	0.02	0.02	psi/in
Resistance, R			
R_1	0.43	-0.38	psi
R_2	0.43	-0.38	psi
Yield Displacement, x			
x1	3.72	-3.29	in
x2	7.12	-7.12	in
Equiv Yield Defl., X_E	3.72	-3.29	in

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the beam. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below. For this problem, the calculated maximum dynamic displacement of the beam is 20.7 inches. This corresponds to a ductility ratio of 5.57 and a support rotation of 7.9 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Note that the calculated response must meet only the support rotation criteria sine there is no ductility limitation for this type of component at this level of protection.

SBEDS also calculates the shear capacity of the component and the peak reactions. This is displayed below the Results Summary box in the Equivalent Static Reactions box. For this case the shear capacity is considerably higher than the reaction, therefore, a "Shear is OK" message is displayed.

The user defined shape and material properties can be saved to a file for a subsequent analysis of this beam shape by using the blue Save User Defined Shape and Save User Defined Material buttons as shown on the Steel Beams input sheet below. The corresponding Retrieve buttons can be used to read in the User Defined shape and material properties from the saved files into the One-Way Steel Beam or Beam Column worksheet for another analysis.

Results Summary					
θ_{max} =	7.86	deg.	Design Criteria:	LLOP/Secondary-NS	
μ =	5.57		Response OK compared to input design criteria		
X_{max} Inbound =	20.71	in	at time =	61.53	msec
X_{min} Rebound =	0.00	in	at time =	0.00	msec
R_{max} =	0.66	psi	at time =	61.53	msec
R_{min} =	-0.38	psi	at time =	109.20	msec
Shortest Yield Line Distance to Determine θ:				150.0	in
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
V_uL =				4,792	lb
V_uR =				2,875	lb
Shear Capacity					
Shear Capacity: V_s =				18,448	lb
Results based on Max Shear Region				Shear is OK	

* Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.

Example 4B: One-Way Steel Beam or Beam-Column (Metric)

Analyze the response of a steel column to the effects of a blast load generated by 250 kg of TNT at 50 meters with an angle of incidence of 20 degrees. The columns in this building have a height of 4.5 m and are spaced at 6.5 m on center. The columns are UC203x203x86 (A992 rolled shapes) and support a maximum static axial load of 300,000 N. This is calculated as specified in PDC TR-06-08 Rev 1 to conservatively include the effects of the dynamic reaction from roof members. Fixed-simple supports are assumed and 2% of critical damping for the analysis. Check the response for conformance with LLOP of a primary type component, since it is a framing component supporting other components, with combined flexure and compression.

Conservatively, it is assumed in this case that the building cladding transfers the blast load into the columns over the whole area between the columns. Building cladding often spans vertically and therefore does not load columns, or it may have a small blast capacity relative to the applied blast load that limits the transferred blast load. In the latter case, it may be more realistic to apply the dynamic reaction pressure history from the cladding rather than the actual blast load. Example 3A shows the process of saving a dynamic reaction pressure history from a component after a SDOF analysis in SBEDS to a file on the computer hard drive and then reading this file into SBEDS as an applied blast load in a subsequent SDOF analysis of the supporting component. Also, it is possible that only a limited width of the the panel directly in front of the column will load the column.

Analysis Parameters:

- Span length is 4.5 m
- Beam/column spacing and supported width is 6.5 m
- Beam/column size is UC203x203x86 (A992 rolled shapes)
- Static axial load is 300,000 N
- Fixed-simple supports
- LLOP for a primary type component
- 2% of critical damping
- Blast load from 250 kg of TNT at 50 meters with an angle of incidence of 20 degrees

Solution

On the “Intro” worksheet area (Figure 1), select “One-Way Steel Beam or Beam Column” and Metric units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) using the information provided in the problem statement. For this particular problem:

- Set the Response Type to “Flexural.”
- On the Structural & Material Properties input box set the Shape Type to “Wide Flange (UC)” and the Shape Size to 203x203x86.
- Select A992 from the steel type drop down menu.
- Under Gravity Displacement select “None(vertical component)”
- Under Blast Load Input Type select “Charge weight and standoff”
- On the Charge Weight and Standoff input box enter the appropriate values for Charge weight and standoff, set the blast load phase to “Positive phase only”, and set the Charge Weight Load Type to “Reflected without Clearing.”
- Enter 20 for Incidence angle

- Set the Response Criteria to “Flex & Comp – compact section” and LLOP/Primary
- On the solution control input box, enter a time step for the analysis equal or smaller than the recommended value and apply 2% of critical damping
- Set the Dynamic Axial Load input cell to “No Dynamic Axial Load”

The input screen should look as shown on the next page.

Steel Beam or Beam-Column

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

Span, L:	4500	mm
Spacing, B:	6500	mm
Boundary Conditions:	Fixed-Simple, Uniformly Loaded	
Response Type:	Flexural	

Structural & Material Properties

Axis of Bending: Strong (X-X)	Shape Type:	Wide Flange (UC)
Click to Define User Shape	Shape Size:	203X203X86
Self-Weight, w:	86.1	kg/m
Moment of Inertia, I:	94500000	mm^4
Section Modulus: Z (hot-rolled beam) or S (cold-formed beam):	977000	mm^3
Web Thickness, tw:	13	mm
Depth, d:	222	mm
Area, A:	11000	mm^2
Supported Weight, W:	10	kg/m^2
Loaded Area Factor - Enter 1.0 for Uniform Load	1	
Inbound Unbraced Length for Compression Flange, L_{br}:	500	mm (0 for fully braced)
Rebound Unbraced Length for Compression Flange, L_{br}:	500	mm (0 for fully braced)
Material Type:	A992, A913, A572, A529 (All Gr. 345) rolled steel shapes	
Yield Strength, f_y:	345	MPa
Ultimate Strength, f_u:	483	MPa
Elastic Modulus, E:	200,000	MPa
Static Strength Increase Factor:	1.05	
Dynamic Increase Factor:	1.19	
Dynamic Yield Stress, f_{dy}:	431	MPa
No Dynamic Axial Load	[4] Static Axial Load, P: 300000	N
Leave blank for No Dynamic Axial Load		
Leave Blank for No Tension Membrane	0	

Click to Define User Material | Save User Defined Shape | Retrieve User Defined Shape | Save User Defined Material | Retrieve User Defined Material

Calculated Properties

Inbound Moment Capacity, M_i:	391,557,945	N-mm
Rebound Moment Capacity, M_r:	391,557,945	N-mm
Rebound/Inbound Moment Capacity Ratio, MR:	1.00	
Ratio of Axial Load to Axial Load Capacity	0.070292956	

See All COE Response Criteria

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (kPa)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (kg TNT)	R (m)
250	50

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected without Clearing

Parameters for Reflected Loads

Wall Height (m)[1]	
Wall Width (m)[1]	
Incidence Angle[2]	20

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Applied Blast Input File Not Selected

Response Criteria

Flex & Comp - compact section

LOP/Type: LLOP/Primary

θ (deg)	μ
3	3

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (simple support) =	0.08	0.12
R (simple support) =	0.29	0.30
F (fixed support) =	0.19	0.12
R (fixed support) =	0.43	0.46

Solution Control

Inbound Natural Period:	23.36	ms
Rebound Natural Period:	23.36	ms
Max Recommended Time Step:	0.06	ms
Time Step:	0.03	ms
% of Critical Damping:	2	%
Initial Velocity:	0	mm/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	23.25	23.25	kg/m^2
Load-Mass Factors, K_{LM}			
K_{LM1}	0.78	0.78	
K_{LM2}	0.78	0.78	
K_{LM3}	0.66	0.66	
Stiffness, K			
K_1	1.31	1.31	kPa/mm
K_2	0.54	0.54	kPa/mm
K_3	0.00	0.00	kPa/mm
Resistance, R			
R_1	23.80	-23.80	kPa
R_2	35.70	-35.70	kPa
Yield Displacement, x			
x1	18.14	-18.14	mm
x2	39.99	-39.99	mm
Equiv Yield Defl., X_E	31.46	-31.46	mm

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the column. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below. For this problem, the calculated maximum dynamic displacement is 63.9 mm. This corresponds to a ductility ratio of 2.03 and a support rotation of 1.63 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Note that the calculated response must be less than or equal to the criteria for both support rotation and ductility to be considered acceptable. Under the Results Summary, SBEDS displays the calculated reactions and shear capacity of the component. For this example, the shear capacity is adequate as indicated by the "Shear is OK" message.

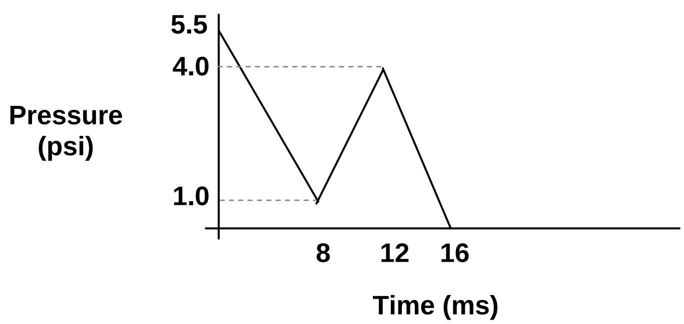
Results Summary					
θ_{max} =	1.63 deg.	Design Criteria:	LLOP/Primary		
μ =	2.03	Response OK compared to input design criteria			
X_{max} =	63.89	mm	at time =	14.04	msec
X_{min} =	0.00	mm	at time =	0.00	msec
R_{max} =	35.70	kPa	at time =	14.04	msec
R_{min} =	-20.07	kPa	at time =	27.15	msec
Shortest Yield Line Distance to Determine θ:				2250.0	mm
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
$V_u L$ =				652,597	N
$V_u R$ =				391,558	N
Shear Capacity					
Shear Capacity: V_s =				668,911	N
Results based on Max Shear Region				Shear is OK	

* Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane.

Example 5A: Metal Stud Wall (English)

Analyze the flexural response of a metal stud wall on a one-story building subject to a blast load as defined below. This is a simplified representation of a multi-peak blast load. The simplified representation preserves the peak pressures from each pulse, the impulse within each pulse, and the approximate shape.

Normally, an advantage of a simplified, point-wise continuous blast load is that it can be entered directly into SBEDS with the Manual Input option for the Blast Load (the pressure history below can be defined with 5 time-pressure pairs). However, this example will demonstrate the case where a user input pressure history cannot be defined within the 8 time-pressure pairs available for the Manual Input option in SBEDS; therefore the user must create a file that is read into SBEDS with the Read Pressure-History option for the Blast Load. Up to 2000 time-pressure pairs can be read into SBEDS. A detailed point-wise continuous representation of an applied blast load, such at that from a blast pressure gage or a computer code that calculates blast pressures (i.e., BLASTX or CONWEP), can be also read in from a file. This is discussed in Example 8B.



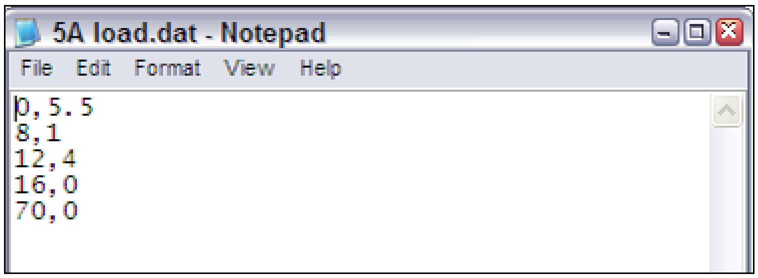
The wall is composed of 800S250-68 (Grade 33) studs that are very closely spaced at 6 inches on center. The wall is 10 ft tall and is assumed to support 2 psf of load. Assume simple-simple supports for analysis where the studs are connected to the runners at the top and bottom. The stud wall is load-bearing, and is therefore a primary component, which must provide a LLOP. It supports metal wall panels and interior gypsum wall that together weigh approximately 2 psf. The studs will be assumed to have standard web punch-outs for passing conduit through the wall area. The stud wall supports one end of the open web steel joists from Example 3A. The dynamic reaction load from the joists applies a dynamic axial load to the stud wall, which was saved in Example 3A to a data file.

Analysis Parameters:

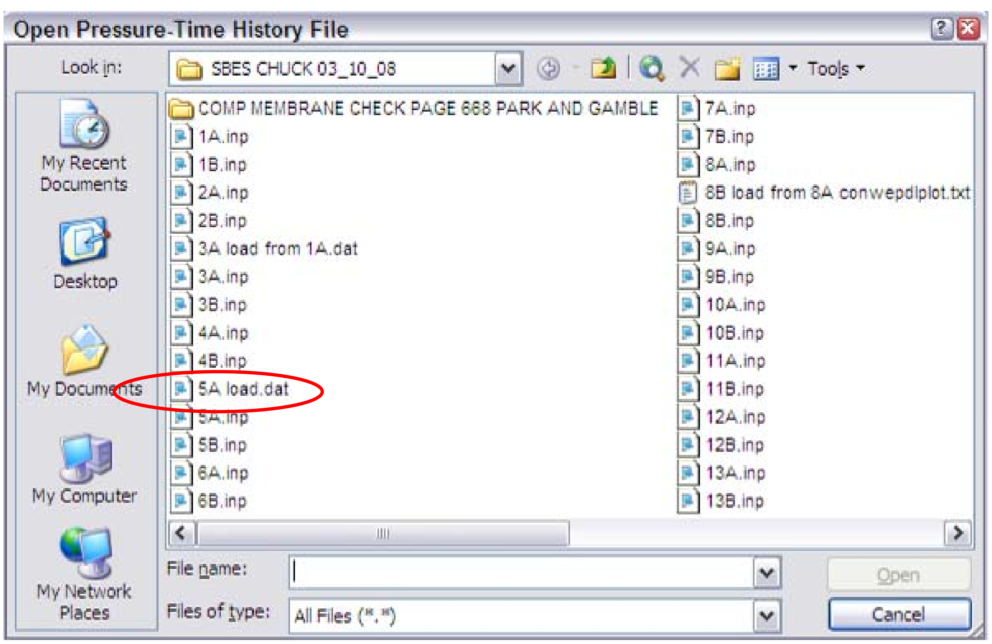
- Stud span length L = 10 ft.
- Stud spacing B = 6 in = 0.5 ft
- Supported weight 2 psf
- Simple-simple supports
- 800S250-68 (Grade 33) studs
- LLOP for a primary type component
- Dynamic axial load from open web steel joists in Example 3A

Solution

For this particular problem, a pressure-history file will be created based on the load description given in the problem statement. To do this, open any text editor (i.e., the *Notepad* application) and enter (time, pressure) pairs – one pair per line - that define the pressure history curve as shown below. It is good practice to include the final (time, pressure) pair as shown below that defines a constant zero pressure at the end of the expected response time of the component, but it is not necessary in SBEDS when the final input pressure is zero. Note that the (time, pressure) pairs are entered with the time values on the left and the pressure values on the right separated by a comma. After entering the values, save the file in ".dat" format. This file will be called *5A load.dat*. This file will be read into SBEDS to define the blast load in this example problem.



After the Pressure-history file has been created, go to the "Intro" worksheet area (Figure 1) and select "Metal Stud Wall" and English units and click the button near the bottom of the page to initiate the component input sheet. This will create the correct input form for SDOF analysis of metal stud walls on the Input sheet in SBEDS. On the Input sheet, use the drop down menu under Blast Load Input Type to select "pressure-time history file". The window shown below will appear.



Select the .dat input file created in the previous step and click "Open" to load the file in SBEDS. The selected filename will appear in the Load Files input box. This is shown in the input screen below.

Use a similar procedure to read in a dynamic axial load on the stud walls applied by the dynamic response of the Open Web Steel Joist component in Example 3A. On the Input sheet, use the drop down menu under Dynamic Axial Load to select “Dynamic axial load”. This will cause a browser window to appear and the file saved at the end of Example 3A can be read in (the filename in this case is 5A dynamic axial load from 3A.dat). The selected filename will appear in the Load Files input box. Note that this dynamic load includes the effects of all static load from the roof, which is included in the saved dynamic reaction load from the joists. Do not input any static axial load from the roof with the dynamic axial load**.** If the building was two-story, the static weight of the second floor and second floor wall would be input as static axial load rather than being included with the dynamic axial load. For the one-story building in this example, do not input static axial load.

After the applied pressure-history and dynamic axial load are read into SBEDS, fill in the rest of the yellow input cells as follows:

- Set the Boundary Conditions to “Simple-Simple, Uniformly Loaded”
- Set the Response type to “Flexural”
- On the Structural & Material Properties input box select 800S250-68 using the drop down menu under Shape.
- Set the Web Punch-outs input cell to “Standard Web Punch-Outs”
- Select “A653, Gr. 33 (steel cold-formed)” as the Steel Type
- Select “No Wall/Non-Structural Veneer Wall” since the studs only support panels (not a masonry veneer wall)
- Select “Dynamic Axial Load per Unit Width” and browse to find the saved dynamic reaction pressure history file from Example 3A
- Set the Response Criteria to “Connected top and bottom” and LLOP/Primary.
- On the Solution Control select a time step equal or less than the recommended value.

The input screen will look as shown on the next page.

Metal Stud Wall

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

Wall Span, L:	10 ft
Stud Spacing, B:	0.5 ft
Boundary Conditions:	Simple-Simple, Uniformly Loaded
Response Type:	Flexural

Structural & Material Properties

Axis of Bending: Strong (X-X)

Shape: 800S250-68

Click for User Defined Shape

Stud Self-Weight, w:	3.33 lb/ft
Moment of Inertia, I:	9.261 in^4
Section Modulus; S:	2.24 in^3
Web Thickness, tw:	0.0713 in
Depth, d:	8 in
Area, A:	0.98 in^2
Web Punch-Outs	Standard Web Punch-Outs
Supported Weight (Exclusive of Structural Veneer Wall), w_s:	2 psf
Dynamic Axial Load Per Unit Width / * Static Axial Load, P'	0 lb/in
Leave Blank	0
Steel Type:	A653, Gr. 33 (steel cold-formed)
Yield Strength, f_y:	33,000 psi
Ultimate Strength, f_u:	45,000 psi
Elastic Modulus, E:	29000000 psi
Static Strength Increase Factor:	1.21
Dynamic Increase Factor:	1.1
Dynamic Yield Stress, f_{dy}:	43,923 psi
Veneer Wall Type:	No Wall/Non-Structural Veneer Wall

Click for User Defined Material

Click for User Defined Masonry

Calculated Properties

Metal Stud Moment Capacity, M_s:	98,388 lb-in
Veneer Wall Moment Capacity, M_w:	lb-in/in
Veneer Wall Resistance from Axial Load Arching:	psi
Controlling Tension Membrane Force	0 lb

Blast Load Input Type

Pressure-time history file

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (psi)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (lbs TNT)	R (ft)

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected without Clearing

Parameters for Reflected Loads

Wall Height (ft)[1]

Wall Width (ft)[1]

Incidence Angle[2]

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

5A dynamic axial load from 3A.dat

multi peak blast load.dat

Response Criteria

Connected top and bottom

LOP/Type: LLOP/Primary

θ (deg)	µ
N/A	1

See All COE Response Criteria

Dynamic Shear Factors

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

Solution Control

Inbound Natural Period:	17.00	ms
Rebound Natural Period:	17.00	ms
Max Recommended Time Step:	0.01	ms
Time Step:	0.01	ms
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties

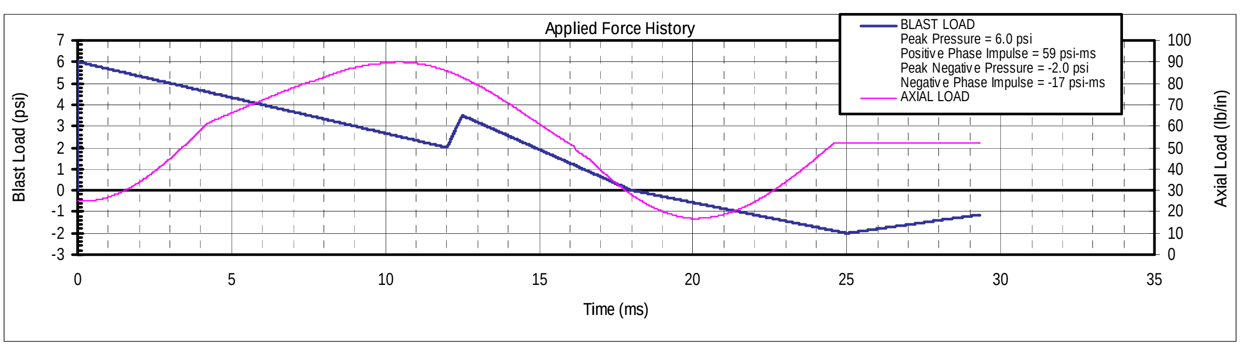
Property	Inbound	Rebound	Units
Mass, M	155.6	155.6	psi-ms²/in
Load-Mass Factors, K_{LM}			
K_{LM1}	0.78	0.78	
K_{LM2}	0.78	0.78	
K_{LM3}	0.66	0.66	
K_{LM4}	0.66	0.66	
K_{LM5}	0.66	0.66	
Stiffness, K			
K_1	16.58	16.58	psi/in
K_2	16.58	16.58	psi/in
K_3	0.00	0.00	psi/in
K_4	0.00	0.00	psi/in
K_5	0.00	0.00	psi/in
Resistance, R			
R_1	9.11	-9.11	psi
R_2	9.11	-9.11	psi
R_3	9.11	-9.11	psi
R_4	9.11	-9.11	psi
Yield Displacement, x			

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the wall stud. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below. For this problem, the calculated maximum dynamic displacement is 0.57 inches. This corresponds to a ductility ratio of 1.03 and a support rotation of 0.54 degrees. Therefore, the response is 3% above the allowable limits. In many cases, response that exceeds the limit amount by a very small percentage (i.e., less than 5%) is acceptable. Notice that for this type of component at LLOP only the ductility is considered for the acceptance criteria.

Under the Results Summary, SBEDS displays the calculated reactions and shear capacity of the component. For this example, the shear capacity is adequate as indicated by the "Shear is OK" message.

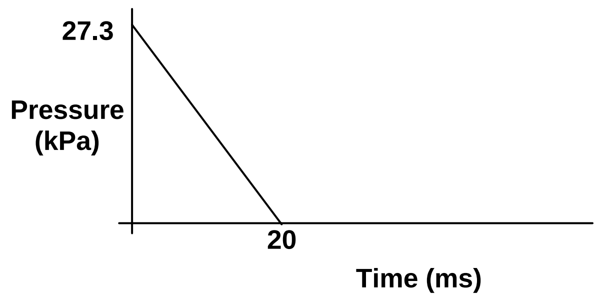
Results Summary					
θ_{max} = 0.54 deg.	Design Criteria:	LLOP/Primary			
μ = 1.03	Response NOT OK compared to input design criteria				
X_{max} Inbound =	0.57	in	at time =	7.61	msec
X_{min} Rebound =	-0.22	in	at time =	16.55	msec
R_{max} =	9.11	psi	at time =	7.61	msec
R_{min} =	-3.92	psi	at time =	16.55	msec
Shortest Yield Line Distance to Determine θ:				60.0	in
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance of Metal Studs: Vu					
$V_u L$ =				3,280	lb
$V_u R$ =				3,280	lb
Shear Capacity (of Metal Studs Only)					
Shear Capacity: V_s =				4848	lb
Results based on Max Shear Region				Shear is OK	
* Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane or masonry veneer strength.					

The pressure history and axial load applied during the SDOF analysis are shown on the Results sheet, as shown below. This pressure vs. time graph corresponds to pressure-history input file, as expected. The axial load is equal to the dynamic reaction pressure history from the open web steel joist in Example 3A multiplied by the joist span. This is the correct axial load for the typical case where the load bearing wall is an exterior wall supporting one joist span.



Example 5B: Metal Stud Wall (Metric)

Analyze the response of a steel stud wall subjected to a blast load as defined below.



The wall height is 3m and the studs are spaced at 0.4 m on center. The wall is comprised of 600S200-43 (Gr. 228) steel studs that are attached with six bolts into steel angles that are anchored into concrete floor and roof slabs. Based on separate calculations and/or testing, the connection is assumed to develop the full tension capacity of the stud. The stud wall has sheathing on both sides and also backs up a 100 mm thick brick veneer wall that is assumed to have a dynamic tensile strength of 1 MPa. The wall must provide a LLOP. It is not load-bearing and is therefore considered a secondary type component.

Analysis Parameters:

- 600S200-43 (Gr. 228) steel studs
- Stud spacing B = 0.4 m.
- Stud length L = 3 m.
- Wall supports 100 mm thick veneer brick wall
- Masonry dynamic tensile strength = 1 MPa
- Simple-simple supports developing full tension membrane capacity of stud
- LLOP for a secondary type component
- Stud is assumed to have typical web punch outs for electrical conduit placement

Solution

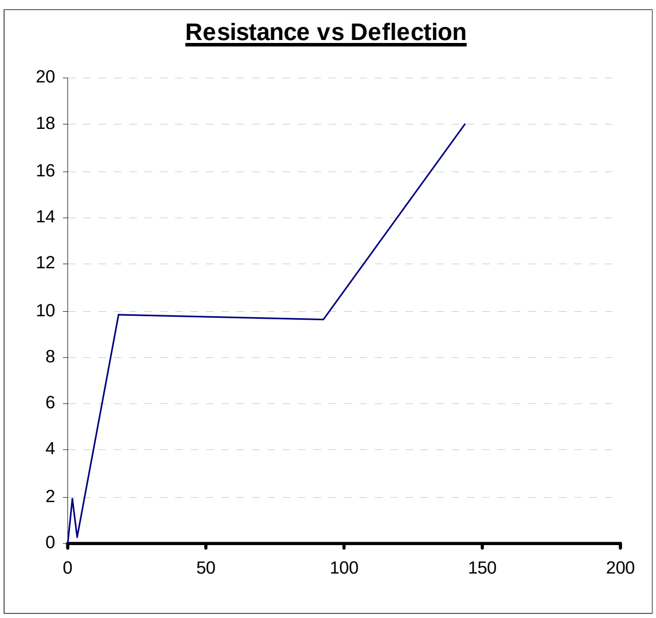
On the "Intro" worksheet area (Figure 1), select "Metal Stud Wall" and Metric units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Select "Simple-Simple, Uniformly Loaded" using the Boundary Conditions drop down menu
- Set the Response Type to "Flexural and Tension Membrane"
- On the Structural & Material Properties input box select the desired shape (600S200-43)
- Select "Standard Web Punch-Outs"
- To use the full tension capacity of the studs to develop tension membrane, enter a value for V_c (Stud Capacity for Tension Membrane) equal or larger than the tension capacity of the stud. SBEDS uses the smallest value between the calculated tension capacity and V_c. In this example, enter 1.0E+6 N for V_c, and SBEDS automatically selects the tension capacity of the studs as the controlling force for tension membrane (See cell D45 in the input sheet). The calculated ultimate tensile capacity of the connection in the plane of the wall can also be input. During tension membrane response there is a small component of

the connection force acting perpendicular to the wall as a shear force, but the resultant of the overall connection force is dominated by the in-plane force.

- Select the appropriate Steel type on the dropdown menu (Gr. 228)
- To account for the additional blast capacity provided by the supported brick, use the drop-down menu next to Veneer Wall type and select "Brick"
- Enter the brick wall thickness (100 mm) the tensile strength (1 MPa). For brick walls, SBEDS automatically assumes a solid section but for completeness the percentage of grouted void space can be input as 100%.
- Select "Manual Input" under Blast Load Input Type and "None (Vertical component)" under Gravity Displacement.
- Enter the appropriate values for pressure and time in the Pressure-Time input section
- Set the response criteria to LLOP/Secondary-NS with full TM capacity
- Select "No Dynamic Axial Load"
- On the Solution Control input box, select a Time Step equal or less that the recommended value by SBEDS.

The input screen will look as illustrated on the next page. A Resistance-Deflection graph is shown to the right of the input area on the Input sheet for most component types. The Resistance-Deflection graph for this case is copied below. It shows how there is an initial "spike" of flexural resistance due to the brick veneer wall, followed by elastic and perfectly plastic flexural response of the metal studs, and finally tension membrane response of the metal studs at deflections greater than 92 mm. The brick veneer wall provides a very small amount of additional resistance after its peak flexural resistance due to axial load arching from its self weight.



Metal Stud Wall

User Info: Fill in Yellow Cells, See Note Below for White Cells		
Wall Span, L:	3000	mm
Stud Spacing, B:	400	mm
Boundary Conditions:	Simple-Simple, Uniformly Loaded	
Response Type:	Flexural and Tension Membrane	

Structural & Material Properties		
Axis of Bending: Strong (X-X)	Shape: 600S200-43	
Click for User Defined Shape		
Stud Self-Weight, w:	2.49	kg/m
Moment of Inertia, I:	1116748.9	mm^4
Section Modulus; S:	14305.907	mm^3
Web Thickness, tw:	1.14554	mm
Depth, d:	152.4	mm
Area, A:	317.42	mm^2
Web Punch-Outs	Standard Web Punch-Outs	
Supported Weight (Exclusive of Structural Veneer Wall), w_s:	0	kg/m^2
No Dynamic Axial Load * Static Axial Load, P':	0	N/m
Stud Support Capacity for Tension Membrane, Vc:	93000	N
Steel Type:	A653, Gr. 228 (cold-formed steel)	
Yield Strength, f_y:	228	MPa
Ultimate Strength, f_u:	320	MPa
Elastic Modulus, E:	200,000	MPa
Static Strength Increase Factor:	1.21	
Dynamic Increase Factor:	1.1	
Dynamic Yield Stress, f_{dy}:	303	MPa
Click for User Defined Material		
Veneer Wall Type:	Brick	
Total Veneer Thickness, h:	100	mm
Masonry Dynamic Tensile Strength, fdt:	1	MPa
Leave Blank for non-CMU Masonry	100	%
Masonry Elastic Modulus, Em:	12,411	MPa
Wall Self-Weight, W:	192.22	kg/m^2
Moment of inertia, I:	83333.33	mm^4/mm
Section Modulus, S:	1666.67	mm^3/mm
Cross Sectional Area, A:	100.00	mm^2/mm
Click for User Defined Masonry		

Calculated Properties		
Metal Stud Moment Capacity, M_s:	4,341,385	N-mm
Veneer Wall Moment Capacity, M_w:	2,167	N-mm/mm
Veneer Wall Resistance from Axial Load Arching:	0.25	kPa
Controlling Tension Membrane Force	74078	N

Blast Load Input Type
Manual input
Gravity Displacement
None (vertical component)

Pressure-Time Input	
Time	Pressure
(ms)	(kPa)
0	27.3
20	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff	
W	R
(kg TNT)	(m)
Blast Load Phase	
Positive phase only	
Charge Weight Load Type	
Reflected without Clearing	
Parameters for Reflected Loads	
Wall Height (m)[1]	
Wall Width (m)[1]	
Incidence Angle[2]	

See notes under error messages

Load Files-AXIAL(above),BLAST(below)	
AxialLoad Input File Not Selected	
Blast Load File Not Selected	
Response Criteria	
With full TM capacity	
LOP/Type	LLOP/Secondary-NS
θ (deg)	µ
2	2

See All COE Response Criteria

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

Solution Control		
Inbound Natural Period:	78.84	ms
Rebound Natural Period:	78.84	ms
Max Recommended Time Step:	0.22	ms
Time Step:	0.2	ms
% of Critical Damping:	0	%
Initial Velocity:	0	mm/ms

SDOF Properties			
Property	Inbound	Rebound	Units
Mass, M	198.4	198.4	kg/m^2
Load-Mass Factors, K_{LM}			
K_{LM1}	0.78	0.78	
K_{LM2}	0.66	0.78	
K_{LM3}	0.66	0.66	
K_{LM4}	0.66	0.66	
K_{LM5}	0.66	0.66	
Stiffness, K			
K_1	0.98	0.53	kPa/mm
K_2	-0.98	0.53	kPa/mm
K_3	0.66	0.00	kPa/mm
K_4	0.00	0.00	kPa/mm
K_5	0.16	0.16	kPa/mm
Resistance, R			
R_1	1.93	-9.65	kPa
R_2	0.25	-9.65	kPa
R_3	9.85	-9.65	kPa
R_4	9.62	-9.65	kPa
Yield Displacement, x			

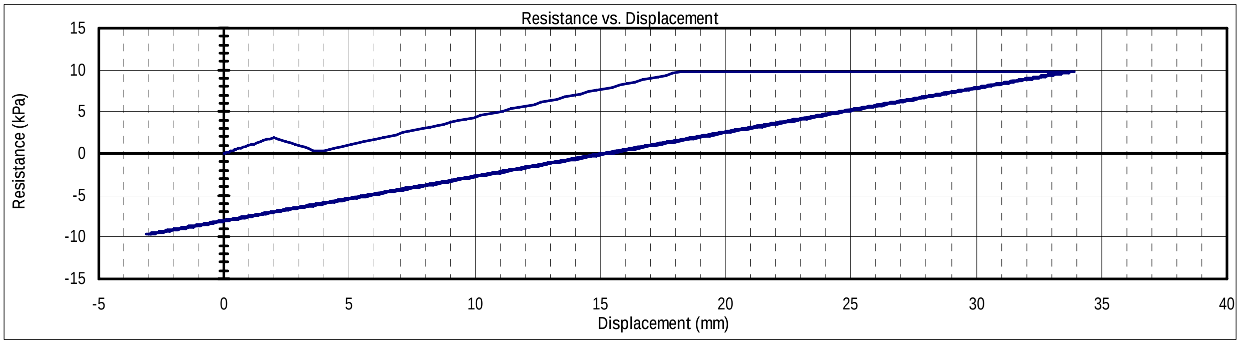
After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the wall stud. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below. For this problem, the calculated maximum dynamic displacement is 33.88 mm. This corresponds to a ductility ratio of 1.86 and a support rotation of 1.29 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the calculated response must be less than or equal to the criteria for both support rotation and ductility to be considered acceptable.

Under the Results Summary, SBEDS displays the calculated reactions and shear capacity of the component. For this example, the shear capacity is adequate as indicated by the "Shear is OK" message.

Results Summary						
θ_{max} =	1.29	deg.	Design Criteria:	LLOP/Secondary-NS		
μ =	1.86		Response OK compared to input design criteria			
X_{max} Inbound =	33.88	mm	at time =	37.60	msec	
X_{min} Rebound =	-3.09	mm	at time =	91.00	msec	
R_{max} =	9.85	kPa	at time =	17.40	msec	
R_{min} =	-9.65	kPa	at time =	91.00	msec	
Shortest Yield Line Distance to Determine θ:				1500.0	mm	
Equivalent Static Reactions*						
Peak Reactions Based on Ultimate Flexural Resistance of Metal Studs: Vu						
V_uL =				5,789	N	
V_uR =				5,789	N	
Shear Capacity (of Metal Studs Only)						
Shear Capacity: V_s =				7277	N	
Results based on Max Shear Region				Shear is OK		
* Based on larger of inbound and rebound ultimate flexural resistance, not including tension membrane or masonry veneer strength.						

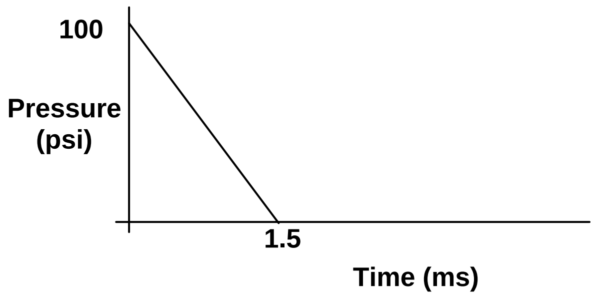
The Resistance vs. Displacement graph for the calculated SDOF response of the stud wall is shown on the Results sheet and is copied below. Note that there is an initial resistance from the brick veneer wall, which has only a small amount of area underneath it. This indicates that the brick wall absorbs only a small amount of strain energy relative to the metal studs and could be omitted from the analysis without very much loss of accuracy. Also, notice that the studs yield plastically in flexure at a displacement of 18 mm and a resistance of 10 kPa.

The Resistance vs. Displacement graph indicates that the stud wall did not deflect far enough to respond with significant tension membrane per the assumptions in the SBEDS methodology as explained in the SBEDS Users Guide (i.e., SBEDS Help document) and the SBEDS Methodology Manual. A deflection of 92 mm is necessary in this case to cause calculated tension membrane. The tension membrane capability is very useful for providing a safety factor against wall failure, but it does not affect the calculated SDOF response in this case. This is typical of many cases because the response limits in SBEDS from PDC TR-06-08 for metal stud walls tend to limit the maximum deflections to less than the deflections where tension membrane becomes significant according to the SBEDS methodology.


Resistance vs. Displacement
Resistance (kPa)
15
10
5
0
-5
-10
-15
-5
0
5
10
15
20
25
30
35
40
Displacement (mm)

Example 6A: One-Way or Two-Way Reinforced Concrete Slab (English)

Analyze the response of a two-way reinforced concrete wall slab with three fixed edges (i.e., no support rotation) and one free edge (at the roof) subjected to a blast load as defined below. The wall frames into a relatively lightweight roof that is not assumed to provide any support to the wall.



The slab is 8 in thick with #6 bars at 12 in on center (O.C.), each face, each way (EFEW). The slab overall dimensions are 20 ft (length) by 12 ft (height). The concrete compressive strength is 3000 psi and the reinforcing steel has a yield strength of 60 ksi. Use MLOP for secondary type components as the required response criteria. A Type I cross section will be assumed for the entire response. The wall is supported by adjacent walls and slabs behind, or inside the wall so that the critical shear section is at a distance “d” from the supports.

Analysis Parameters:
- Two-way slab: L = 20 ft, H = 12 ft
- Thickness = 8 in.
- Three fixed supports
- Reinforcement of #6 bars at 12 in. O.C EFEW
- f'_c = 3000 psi
- f_y = 60000 psi
- MLOP for secondary type component is required
- The wall will not have shear reinforcement, so shear-controlled response will be allowed to control if the wall has a lower shear capacity compared to its flexural capacity

Solution

On the “Intro” worksheet area (Figure 1), select “One-Way and Two-Way Reinforced Concrete Slab” and English units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:
- Length Along Free End (i.e., roof line), L = 20 ft
- Span Along Both Sup’d Sides, H = 12 ft
- Set Boundary Conditions to “Two-Way: Three Sides Supported – All Fixed”
- Select “Flexural Only” and “Type I Cross Section” for Response Type
- On the Structural & Material Properties input box enter:
  - Slab Thickness = 8 in
  - Reinforcing steel spacing = 12 in. in both directions
  - Reinforcing steel Areas, enter 0.44 in^2 for all, since reinforcing is the same both ways and in both faces

  - Clear cover in the L direction = 2.0 in. (both loaded and non-loaded)
  - Clear cover in the H direction = 1.5 in. (both loaded and non-loaded)
  - Supported weight = 0 psf
  - Concrete Density = 150 pcf (Typical value for reinforced concrete)
  - Compressive strength = 3000 psi
  - Concrete Static Strength Increase Factor = 1.0 (Typical value, see SBEDS user manual)
  - Concrete Dynamic Increase Factor = 1.19 (Typical value, see SBEDS user manual)
  - Select Grade 60 Steel Reinforcement from the reinforcing steel dropdown menu
- Select “Manual Input” under Blast Load Input Type, and “None(vertical component)” under Gravity Displacement.
- Enter appropriate values in Pressure-Time input table
- Set Response criteria to “Flexure-no shear reinforcing or TM” and “MLOP/Secondary – NS”
- Select “No Dynamic Axial Load”
- Select a time step value equal or less than the recommended value in SBEDS

The input screen should appear as illustrated on the next page.

One-Way and Two-Way Reinforced Concrete Slab

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

Length Along Free End, L:		20	ft
Span Along Both Sup'd Sides, H:		12	ft
Boundary Conditions:	Two-Way: Three Sides Supported - All Fixed		
Response Type:	Flexural Only	Type I Cross Section	

Structural & Material Properties

	Inbound	Rebound	
Slab Thickness, t:		8	in
Reinforcing Steel Spacing (See diagram in cell R37 for diagram of steel input terms)			
Bars Spanning Parallel to L, b_L:		12	in
Bars Spanning Parallel to H, bH:		12	in
Reinforcing Steel Areas	Inbound	Rebound	
Positive Moment Steel Parallel to L, AspL:	0.44	0.44	in^2
Negative Moment Steel Parallel to L, AsnL:	0.44	0.44	in^2
Positive Moment Steel Parallel to H, AspH:	0.44	0.44	in2
Negative Moment Steel Parallel to H, AsnH:	0.44	0.44	in2
Distance of Cover to Center of Bars: d			
Non-Loaded Side Spanning Parallel to L:		2	in
Loaded Side Spanning Parallel to L:		2	in
Non-Loaded Side Spanning Parallel to H:		1.5	in
Loaded Side Spanning Parallel to H:		1.5	in
Supported Weight, w:		0	psf
Concrete Density, γ:		150	lb/ft^3
Poisson's Ratio, ν:		0.167	
Concrete Compressive Strength, f'_c:		3,000	psi
Concrete Static Strength Increase Factor (>=1):		1.0	
Concrete Dynamic Compr. Increase Factor (>=1):		1.19	
Concrete Dynamic Compr. Strength, f'_{dc}:		3,570	psi
Concrete Elastic Modulus, E_c:		3,320,561	psi
Select Reinforcement:	A615, A616, A706 (All Gr. 60)		
Reinf. Steel Yield Strength, f_y:		60,000	psi
Reinf. Steel Ultimate Strength, f_u:	Click for User Defined Steel	90,000	psi
Static Strength Increase Factor:		1.1	
Dynamic Increase Factor:		1.17	
Dynamic Reinf. Steel Yield Stress, f_{ds}:		77,220	psi
Reinf. Steel Elastic Modulus, E_s:		29000000	psi
Axial Load Input:	No Dynamic Axial Load		
Static Axial Load, P': (Note: Enter P>=0)		0	lb/in
Span Length in Direction of Axial Load		0	ft

See All COE Response Criteria

Blast Load Input Type: Manual input

Gravity Displacement: None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (psi)
0	100
1.5	0
40	0
40	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (lbs TNT)	R (ft)

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected without Clearing

Parameters for Reflected Loads

Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Blast Load File Not Selected

Response Criteria

Flexure-no shear reinforcing or TM

LOP/Type: MLOP/Secondary-NS

θ (deg)	μ
2	N/A

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (long side) =	0.19	0.15
R (long side) =	0.19	0.30
F (short side) =	0.11	0.10
R (short side) =	0.19	0.18

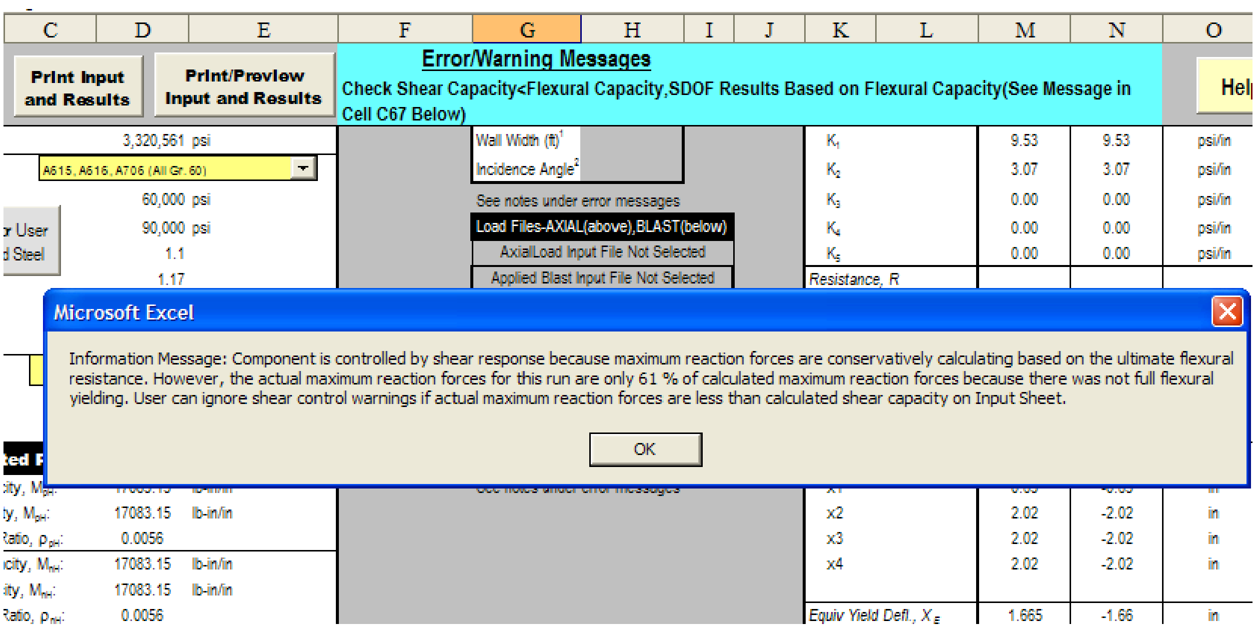
Solution Control

Inbound Natural Period:	70.99	ms
Rebound Natural Period:	70.99	ms
Max Recommended Time Step:	0.15	msec
Time Step:	0.1	msec
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	1797.2	1797.2	$psi\text{-}ms^2/in$
Load-Mass Factors, K_{LM}			
K_{LM1}	0.68	0.68	
K_{LM2}	0.68	0.68	
K_{LM3}	0.52	0.52	
K_{LM4}	0.52	0.52	
K_{LM5}	0.52	0.52	
Stiffness, K			
K_1	9.53	9.53	psi/in
K_2	3.07	3.07	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	6.18	-6.18	psi
R_2	10.39	-10.39	psi
R_3	10.39	-10.39	psi
R_4	10.39	-10.39	psi

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the slab. For this particular problem, the response is controlled by the shear capacity of the slab, which is stated in the Error/Warnings section displayed by SBEDS as shown below. This occurs because the diagonal shear capacity in the Results Summary on the Input sheet is less than the calculated shear forces in the Results Summary at the supports or at a distance "d" from the supports. The shear force at a distance "d" from the support is the relevant value to compare to the calculated shear capacity if the concrete component is supported from the opposite side that is loaded by blast, as discussed in the SBEDS Methodology Manual. Otherwise, the shear force at the face of the supports would be the relevant value to compare to the calculated shear capacity. SBEDS notifies the user of this situation with the message in the yellow cells below the Error/Warnings section near the bottom of the input page, which is copied below.



Note: the following lines are near cell B67 on the input sheet

Error/Warning Messages

Check Shear Capacity<Flexural Capacity,SDOF Results Based on Flexural Capacity(See Message in Yellow Cells Below)

Check Shear Results, Provide Required Stirrups or Set Shear Flag >0 in Cell H45 and ReRun SDOF for Shear Controlled Response

(Shear Flag =1 for Controlling Shear at Support, =2 for Controlling Shear at distance d from Support)

The shear forces in the Results Summary are maximum shear forces based on the ultimate flexural resistance of the walls. Usually in blast design, the blast load causes the component to reach its ultimate flexural resistance so the calculated shear forces are equal to the ultimate values. Even when this is not true, it is typical for blast design to assume that the blast load can be larger than the design blast load, causing the ultimate flexural resistance and the maximum shear forces shown in the Results Summary. Therefore, blast-resistant components are almost always designed to resist the maximum shear forces. This can be accomplished by 1) resizing the reinforcing steel to reduce the ultimate resistance, 2) adding shear reinforcing steel, or 3) increasing the concrete compressive strength (and therefore concrete shear strength). If the required shear reinforcement is added, the shear message can be ignored since SBEDS does not account for shear reinforcing steel when calculating component shear strengths. If the other two approaches are used, the component should be reanalyzed with the shear flag set to zero.

SBEDS also displays an information box for this analysis, as shown above, indicating that the actual shear forces from the calculated component response are only 61% of the shear forces shown in the Results Summary (see below). This occurs because the applied blast load does not cause the component to reach its ultimate resistance. The actual shear force is 61% of the calculated shear force in the Results Summary at a distance "d" from the supports, which is only 482 lb/in, less than the calculated diagonal shear capacity of 746 lb/in. Also, the shear capacity of 746 lb/in is only 5% less than the shear force at a distance "d" from the support of 792 lb/in. Therefore, a design engineer may decide to accept the SBEDS results above in spite of the shear warning for this case.

Results Summary					
θ_{max} =	0.33 deg.	Design Criteria:	MLOP/Secondary-NS		
μ =	0.48	Response OK compared to input design criteria			
X_{max} Inbound =	0.70 in	at time =	18.40 msec		
X_{min} Rebound =	-0.63 in	at time =	53.90 msec		
R_{max} =	6.33 psi	at time =	18.40 msec		
R_{min} =	-6.22 psi	at time =	53.90 msec		
Shortest Yield Line Distance to Determine θ:			120.0 in		
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
Vu at supports in L direction			792.1	lb/in	
Vu at supports in H direction			830.7	lb/in	
Maximum Vu at distance d from support *** =			791.8	lb/in	
Concrete Shear Capacity					
Direct Shear Capacity, (monolithic joint) $V_{c,direct}$ =			3570.0	lb/in	
Diagonal Shear Capacity: $V_{c,diag}$ =			746.9	lb/in	
Tensile steel depth for shear calculations, d:			6.3	in	
Results based on Max Shear Region					
At support:		Stirrups Required			
At distance d from support:		Stirrups Required			

For some cases, it is acceptable to have a structural component that has shear-controlled response to blast loads if the calculated response is acceptable compared to the shear capacity of the component. For example, this may be the case for a existing component that cannot be strengthened in shear for practical reasons. This case will be reanalyzed using an input Shear Flag to demonstrate the analysis of shear-controlled components in SBEDS. In this case the shear flag is 2, as instructed in cell B67 of the Input sheet for cases where the critical shear section is at a distance "d" from the support. An input of the shear flag causes all flexural resistances on the Input sheet to automatically be recalculated by SBEDS so that they do not exceed the ultimate resistance based on the shear capacity of the component. In this case, the ultimate resistance of the component based on the shear capacity at a distance "d" from the support is 9.8 psi. The input sheet looks as shown on the next page after the Shear Flag is input. Note that the response criteria are set to "N/A" in SBEDS for all shear-controlled response (i.e., whenever a Shear Flag is input) because the response criteria used in SBEDS do not include shear-controlled response.

One-Way and Two-Way Reinforced Concrete Slab

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

Length Along Free End, L:		20	ft
Span Along Both Sup'd Sides, H:		12	ft
Boundary Conditions:	Two-Way: Three Sides Supported - All Fixed		
Response Type:	Flexural Only	Type I Cross Section	

Structural & Material Properties

	Inbound	Rebound	
Slab Thickness, t:		8	in
Reinforcing Steel Spacing (See diagram in cell R37 for diagram of steel input terms)			
Bars Spanning Parallel to L, b_L:		12	in
Bars Spanning Parallel to H, bH:		12	in
Reinforcing Steel Areas	Inbound	Rebound	
Positive Moment Steel Parallel to L, AspL:	0.44	0.44	in^2
Negative Moment Steel Parallel to L, AsnL:	0.44	0.44	in^2
Positive Moment Steel Parallel to H, AspH:	0.44	0.44	in2
Negative Moment Steel Parallel to H, AsnH:	0.44	0.44	in2
Distance of Cover to Center of Bars: d_c			
Non-Loaded Side Spanning Parallel to L:		2	in
Loaded Side Spanning Parallel to L:		2	in
Non-Loaded Side Spanning Parallel to H:		1.5	in
Loaded Side Spanning Parallel to H:		1.5	in
Supported Weight, w:		0	psf
Concrete Density, γ:		150	lb/ft^3
Poisson's Ratio, ν:		0.167	
Concrete Compressive Strength, f'_c:		3,000	psi
Concrete Static Strength Increase Factor (>=1):		1.0	
Concrete Dynamic Compr. Increase Factor (>=1):		1.19	
Concrete Dynamic Compr. Strength, f'_{dc}:		3,570	psi
Concrete Elastic Modulus, E_c:		3,320,561	psi
Select Reinforcement:	A615, A616, A706 (All Gr. 60)		
Reinf. Steel Yield Strength, f_y:		60,000	psi
Reinf. Steel Ultimate Strength, f_u:	Click for User Defined Steel	90,000	psi
Static Strength Increase Factor:		1.1	
Dynamic Increase Factor:		1.17	
Dynamic Reinf. Steel Yield Stress, f_{ds}:		77,220	psi
Reinf. Steel Elastic Modulus, E_s:		29000000	psi
Axial Load Input:	No Dynamic Axial Load		
Static Axial Load, P': (Note: Enter P>=0)		0	lb/in
Span Length in Direction of Axial Load		0	ft

Calculated Properties

See All COE Response Criteria

Blast Load Input Type
Manual input
Gravity Displacement
None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (psi)
0	100
1.5	0
40	0
40	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (lbs TNT)	R (ft)
Blast Load Phase	
Positive phase only	
Charge Weight Load Type	
Reflected without Clearing	
Parameters for Reflected Loads	
Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	

See notes under error messages

Load Files-AXIAL(above),BLAST(below)
AxialLoad Input File Not Selected
Applied Blast Input File Not Selected

Response Criteria

Flexure-no shear reinforcing or TM	
LOP/Type	MLOP/Secondary-NS
θ (deg)	μ
N/A	N/A
Shear Flag[5]	2

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (long side) =	0.19	0.15
R (long side) =	0.19	0.30
F (short side) =	0.11	0.10
R (short side) =	0.19	0.18

Solution Control

Inbound Natural Period:	70.99	ms
Rebound Natural Period:	70.99	ms
Max Recommended Time Step:	0.15	msec
Time Step:	0.1	msec
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	1797.2	1797.2	$psi\text{-}ms^2/in$
Load-Mass Factors, K_{LM}			
K_{LM1}	0.68	0.68	
K_{LM2}	0.68	0.68	
K_{LM3}	0.52	0.52	
K_{LM4}	0.52	0.52	
K_{LM5}	0.52	0.52	
Stiffness, K			
K_1	9.53	9.53	psi/in
K_2	3.07	3.07	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	6.18	-6.18	psi
R_2	9.80	-9.80	psi
R_3	9.80	-9.80	psi
R_4	9.80	-9.80	psi
Yield Displacement, x			

After the Shear Flag is input, click the Run SDOF button again and the SDOF response is calculated assuming shear controlled response. A warning message is displayed as shown below that the analysis is based on shear controlled response.

Error/Warning Messages

Information Message:Ultimate Flexural Resistance Based on Shear Capacity(For Shear Flag =1 Controlling Shear at Support,For Shear Flag =2 Controlling Shear at distance d from Support)

For this analysis, the maximum calculated displacement was 0.70 inches, which does not change from the previous analysis since the component resistance is in the elastic range regardless of whether the ultimate resistance is based on the shear or flexural capacity. The calculated maximum deflection corresponds to a ductility ratio of 0.50 and a support rotation of 0.33 degrees. The ductility ratio is based on an equivalent yield deflection, x_e, which is calculated with the ultimate resistance based on the shear capacity rather than the flexural capacity.

Results Summary				
θ_{max} = 0.33 deg.	Design Criteria:	MLOP/Secondary-NS		
μ = 0.50		No response criteria specified		
X_{max} Inbound =	0.70 in	at time =	18.40 msec	
X_{min} Rebound =	-0.63 in	at time =	53.90 msec	
R_{max} =	6.33 psi	at time =	18.40 msec	
R_{min} =	-6.22 psi	at time =	53.90 msec	
Shortest Yield Line Distance to Determine θ:			120.0 in	
Equivalent Static Reactions*				
Peak Reactions from Shear Controlled Response: Vu_s				
Vu at supports in L direction			747.2	lb/in
Vu at supports in H direction			783.6	lb/in
Maximum Vu at distance d from support *** =			746.9	lb/in
Concrete Shear Capacity				
Direct Shear Capacity, (monolithic joint) $V_{c,direct}$ =			3570.0	lb/in
Diagonal Shear Capacity: $V_{c,diag}$ =			746.9	lb/in
Tensile steel depth for shear calculations, d:			6.3	in
Results based on Max Shear Region				
At support:		Stirrups Required		
At distance d from support:		Shear is OK		
*Required Stirrups, Av based on Max Shear Region***				
For critical section @ support, A_{v,req_s}:			0.0001	in²/in²
For critical section at d, A_{v,req_d}:			0.0000	in²/in²

* Based on larger of inbound and rebound ultimate flexural resistance, not including tension or compression membrane.

**Multiply Av values by flexural bar spacing and stirrup spacing to get stirrup area

*** Vmax at distance d from support is conservatively overestimated

Since SBEDS does not include response criteria for shear-controlled response, it is useful to consider response criteria that are published by other organizations for blast resistant design. A task committee of the American Society of Civil Engineers (ASCE) on Blast Resistant Design of the Petrochemical Facilities publishes the manual *Design of Blast Resistant Buildings in Petrochemical Facilities*, which has criteria for reinforced concrete components controlled by shear response. (A reference for this document is shown at the end of this example problem.) The ASCE response criteria for shear-controlled response and the corresponding damage level definitions are shown in the following tables. Based on these response criteria, the reinforced concrete slab in this example without shear reinforcement should have a maximum ductility ratio of 1.3 for all component damage levels. This is greater than the ductility ratio of 0.44 shown in the Results Summary, and therefore the calculated response is acceptable. The Results Summary indicates that the concrete shear capacity is adequate at a distance "d" from the supports, as expected since the ultimate resistance of the component in this analysis is based on its shear strength. (See Example 9A for note regarding shear distribution around openings.)

ASCE* Response Limits for Reinforced Concrete (R/C) and Reinforced Masonry (R/M) Components Controlled by Shear Response

Component	**Low Response**		**Medium Response**		**High Response**	
	μ_a	θ_a	μ_a	θ_a	μ_a	θ_a
R/C and R/M Shear Walls & Diaphragms	3		3		3	
R/C and R/M Components (shear control, without shear reinforcement)	1.3		1.3		1.3	
R/C and R/M Components (shear control, with shear reinforcement)	1.6		1.6		1.6	

ASCE* Component Damage Level Descriptions

Damage Level	**Description**
High	Component has not failed, but it has significant permanent deflections causing it to be unrepairable
Medium	Component has some permanent deflection. It is generally repairable, if necessary, although replacement may be more economical and aesthetic
Low	Component has none to slight visible permanent damage

*ASCE Task Committee on Blast Resistant Design, *Design of Blast Resistant Buildings in Petrochemical Facilities*, American Society of Civil Engineers, N.Y., N.Y., 1997. (To be updated in 2008).

Example 6B: One-Way or Two-Way Reinforced Concrete Slab (Metric)

Analyze the response of a two-way reinforced concrete slab with four fixed edges subjected to a blast load generated by 900 kg of TNT at 10 m. Assume full blast load reflection and include negative phase blast load in the analysis. The slab is 305 mm thick with 12.8 mm bars at 300 mm on center, both ways, placed at mid-thickness. The slab overall dimensions are 7 m (length) by 4 m (height). The concrete compressive strength is 28 MPa and the reinforcing steel has yield strength of 275 MPa. Use LLOP for secondary type components as the Response Criteria. The slab is monolithic with surrounding cast-in-place concrete construction and has continuously spliced reinforcing steel at each face. Assume that the slab can develop tension and compression membrane response. This slab is part of military facility that must meet DoD design criteria for explosives safety. Therefore, a Type II cross section must be assumed when the component response exceeds 2 degrees of support rotation. (Note that the response criteria provided by SBEDS is primarily for anti-terrorism/force protection and may not be appropriate for other situations such as explosives safety. In those cases the “User Defined” option should be selected from the Response Criteria drop-down menu.)

Analysis Parameters:

- Two-way slab: L = 7 m, H = 4 m
- Thickness = 305 mm
- Four fixed supports
- Reinforcement of 12.8 mm bars at 300 mm on center, both ways, at mid-thickness
- f'_c = 28 MPa
- f_y = 275 MPa for reinforcing steel
- LLOP for secondary type component is required
- 875 kg of TNT at 12 m. Fully reflected with positive and negative phase blast load

Solution

On the “Intro” worksheet area (Figure 1), select “One-Way and Two-Way Reinforced Concrete Slab” and Metric units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Long dimension span, L = 7000 mm
- Short dimension span , H = 4000 mm
- Set Boundary Conditions to “Two-Way: Four Sides Supported – All Fixed”
- Select “Flexural, Tension, & Compression Membrane” and “ include Type II Cross Section” for Response Type
- On the Structural & Material Properties input box enter:
    - Slab Thickness = 305 mm
    - Reinforcing steel spacing = 300 mm in both directions
    - Reinforcing steel Areas, enter 129 mm^2 for all, since reinforcing is the same both ways and is placed at mid-thickness (i.e., same for inbound and rebound)
    - Clear cover in the L direction = 152.5 mm (both loaded and non-loaded)
    - Clear cover in the H direction = 152.5 mm (both loaded and non-loaded)
    - Supported weight = 0 kg/m^2
    - Concrete Density = 2400 kg/m^3 (Typical value for reinforced concrete)
    - Compressive strength = 28 MPa

  - o Concrete Static Strength Increase Factor = 1.0 (Typical value, see SBEDS user manual)
  - o Concrete Dynamic Increase Factor = 1.19 (Typical value, see SBEDS user manual)
  - o Select Grade 275 Steel Reinforcement
- Select “Charge weight and standoff” under Blast Load Input Type, and “None (vertical component)” under Gravity Displacement.
- Enter appropriate values in the Charge Weight and Standoff input box, and the “Positive and negative phase” and “Reflected without Clearing” dropdown box selections
- Enter 0 on cell H35 for Incidence Angle to include full reflection
- Set Response criteria to “Flexure-shear reinforcing & TM” and “LLOP/Secondary –NS”
- Select “No Dynamic Axial Load”
- Select a time step value equal or less than the recommended value in SBEDS

The input screen should appear as illustrated on the next page.

One-Way and Two-Way Reinforced Concrete Slab

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

Long Span Dimension, L:		7000	mm
Short Span Dimension, H:		4000	mm
Boundary Conditions:	Two-Way: Four Sides Supported - All Fixed		
Response Type:	Flexural,Tension,&Compression Membra	Include Type II Section	

Structural & Material Properties

	Inbound	Rebound	
Slab Thickness, t:		305	mm
Resinforcing Steel Spacing (See diagram in cell R37 for diagram of steel input terms)			
Bars Spanning Parallel to L, b_L:		300	mm
Bars Spanning Parallel to H, bH:		300	mm
Reinforcing Steel Areas	Inbound	Rebound	
Positive Moment Steel Parallel to L, AspL:	129	129	mm^2
Negative Moment Steel Parallel to L, AsnL:	129	129	mm^2
Positive Moment Steel Parallel to H, AspH:	129	129	mm2
Negative Moment Steel Parallel to H, AsnH	129	129	mm2
Distance of Cover to Center of Bars: d			
Non-Loaded Side Spanning Parallel to L:		52	mm
Loaded Side Spanning Parallel to L:		52	mm
Non-Loaded Side Spanning Parallel to H:		38	mm
Loaded Side Spanning Parallel to H:		38	mm
Supported Weight, w:		0	kg/m^2
Concrete Density, γ:		2400	kg/m^3
Poisson's Ratio, ν:		0.167	
Concrete Compressive Strength, f'_c:		28	MPa
Concrete Static Strength Increase Factor (>=1):		1.0	
Concrete Dynamic Compr. Increase Factor (>=1):		1.19	
Concrete Dynamic Compr. Strength, f'_{dc}:		33	MPa
Concrete Elastic Modulus, E_c:		26,752	MPa
Select Reinforcement:	A615, Gr. 275		
Reinf. Steel Yield Strength, f_y:	Click for User Defined Steel	275	MPa
Reinf. Steel Ultimate Strength, f_u:		517	MPa
Static Strength Increase Factor:		1.1	
Dynamic Increase Factor:		1.17	
Dynamic Reinf. Steel Yield Stress, f_{ds}:		354	MPa
Reinf. Steel Elastic Modulus, E_s:		200,000	MPa
Axial Load Input:	No Dynamic Axial Load		
Static Axial Load, P': (Note: Enter P>=0)		0	N/m
Span Length in Direction of Axial Load		0	mm

See All COE Response Criteria

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time	Pressure
(ms)	(kPa)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W	R
(kg TNT)	(m)
900	10
Blast Load Phase	
Positive and negative phase	
Charge Weight Load Type	
Reflected without Clearing	
Parameters for Reflected Loads	
Wall Height (m)[1]	
Wall Width (m)[1]	
Incidence Angle[2]	0

See notes under error messages

Load Files-AXIAL(above),BLAST(below)		
AxialLoad Input File Not Selected		
Applied Blast Input File Not Selected		
Response Criteria		
Flexure-shear reinforcing, no TM		
LOP/Type	LLOP/Secondary-NS	
θ (deg)	**µ**	
6	N/A	

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (long side) =	0.12	0.10
R (long side) =	0.24	0.25
F (short side) =	0.06	0.05
R (short side) =	0.09	0.10

Solution Control

Inbound Natural Period:	23.95	ms
Rebound Natural Period:	23.95	ms
Max Recommended Time Step:	0.07	msec
Time Step:	0.05	msec
% of Critical Damping:	0	%
Initial Velocity:	0	mm/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	732.0	732.0	kg/m^2
Load-Mass Factors, K_{LM}			
K_{LM1}	0.73	0.73	
K_{LM2}	0.56	0.56	
K_{LM3}	0.56	0.56	
K_{LM4}	0.56	0.56	
K_{LM5}	0.56	0.56	
Stiffness, K			
K1	36.78	36.78	kPa/mm
K2	2.56	0.00	kPa/mm
K3	-3.10	2.53	kPa/mm
K4	0.00	-3.10	kPa/mm
K5	0.13	0.00	kPa/mm
Resistance, R			
R1	71.38	-71.38	kPa
R2	404.85	-71.38	kPa
R3	57.32	-404.85	kPa
R4	57.32	-57.32	kPa

After the input sheet is completed click the “Run SDOF” button at the top of the screen (See Figure 2) to calculate the dynamic response of the slab. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below. For this problem, the calculated maximum dynamic displacement is 302 mm. This corresponds to a support rotation of 8.60 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the calculated response for this type of component at this Level of Protection is dependant only on support rotation.

Results Summary

θ_{max} =	8.60 deg.	Design Criteria:	LLOP/Secondary-NS
μ =	155.83		Response NOT OK compared to input design criteria

X_{max} Inbound =	302.42	mm	at time =	42.60	msec
X_{min} Rebound =	0.00	mm	at time =	0.00	msec
R_{max} =	404.85	kPa	at time =	9.60	msec
R_{min} =	-71.38	kPa	at time =	48.35	msec
Shortest Yield Line Distance to Determine θ:				2000.0	mm

Equivalent Static Reactions*

Peak Reactions Based on Ultimate Flexural Resistance: Vu		
Vu at supports in L direction	102.8	N/mm
Vu at supports in H direction	105.9	N/mm
Maximum Vu at distance d from support *** =	92.1	N/mm
Concrete Shear Capacity		
Direct Shear Capacity, (monolithic joint) $V_{c,direct}$ =	1386.1	N/mm
Diagonal Shear Capacity: $V_{c,diag}$ =	250.1	N/mm
Tensile steel depth for shear calculations, d:	260.0	mm
Results based on Max Shear Region		
At support:	Shear is OK	
At distance d from support:	Shear is OK	
*Required Stirrups, Av based on Max Shear Region***		
For critical section @ support, A_{v,req_s};	0.0000	mm^2/mm^2
For critical section at d, A_{v,req_d};	0.0000	mm^2/mm^2

* Based on larger of inbound and rebound ultimate flexural resistance, not including tension or compression membrane.

**Multiply Av values by flexural bar spacing and stirrup spacing to get stirrup area

*** Vmax at distance d from support is conservatively overestimated

Under the Results Summary, SBEDS displays the calculated reactions and shear capacity of the component. For this example, the shear capacity is adequate as indicated by the “Shear is OK” message. (See Example 9A for note regarding shear distribution around openings.)

There is an error/warning message for this analysis, as copied below.

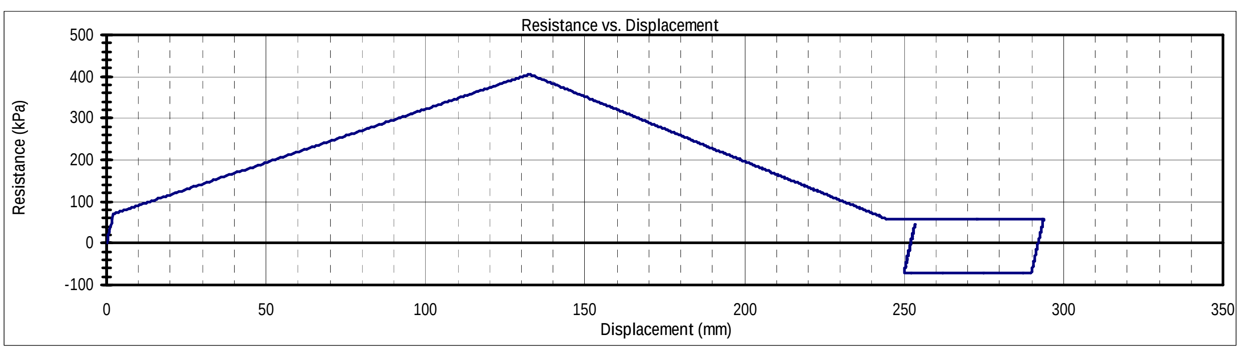
Error/Warning Messages

Stirrups may be req'd for compression reinforcing since support rotation > 2 deg, Warning: Scaled Standoff < 1.2 m/kg1/3, Blast Loads May Not be Uniform Over Full Loaded Area as Assumed

This warning states that stirrups may be required for compression reinforcement since the calculated response of the component exceeds 2 degrees of support rotation. Therefore, even though stirrups are not needed to resist shear, some blast design criteria require stirrups to laterally brace the compression face reinforcing steel because of concerns that the concrete will crush in the maximum moment region at support rotations greater than 2 degrees. In this case the stirrups can be designed similar to ties for reinforced concrete columns. These concerns are probably most applicable for very high steel reinforcing ratios that are required in buildings designed to resist very close-in explosions or confine the effects of large internal explosions.

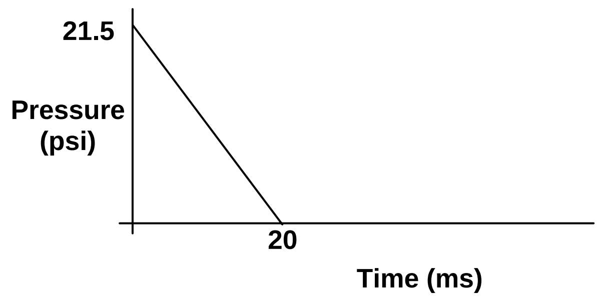
This Error/Warning Message also states that the scaled standoff (i.e., standoff divided by cube root of charge weight) is less than 1.2 m/kg$^{1/3}$, indicating that the blast load is probably not spatially uniform across the blast-loaded area of the component as assumed in the SDOF analysis. In this case, the scaled standoff is 1.06 m/kg$^{1/3}$, which is within 20% of the 1.2 limit value. Also, the calculated response is significantly less than the allowable limit for support rotation. Therefore, no further analysis is considered necessary for this case. UFC 3-340-01 (the DAHS CWE Manual) has a procedure for determining an equivalent uniform blast load for cases where this additional calculation is required. Non-linear, dynamic finite element analyses can also be used to perform analyze the response of blast-loaded components explicitly considering spatially non-uniform blast loads.

The calculated resistance vs. dynamic displacement relationship from the Results sheet is copied below. It shows that the slab yielded in flexure with a dynamic moment capacity based on a full Type I cross section, then immediately responded in compression membrane up to its full compression membrane capacity, and then transitioned into a pure flexural response again with a dynamic moment capacity based on a full Type II cross section at deflections exceeding 2 degrees of support rotation. The slab did not deflect far enough to develop tension membrane response, which would require about 12 degrees of deflection for this case. However, tension membrane capacity in this slab is still beneficial because it provides reserve capacity against failure by blast load.



Example 7A: One-Way Reinforced Concrete Beam or Beam Column (English)

Analyze the response of a 25 ft long reinforced concrete roof joist spaced at 7 ft O.C. and subjected to the following load.



The joists are 12 in x 12 in with 3 #5 bars on the bottom face and 2#6 on the top face, and shear reinforcement. The joists support a 4 in. concrete slab. The joist is required to meet LLOP for secondary type components. The joists are continuous over the supporting girders so a fixed-fixed boundary condition is assumed for analysis. The joists also have continuous reinforcing steel at both faces with full tension splices considering the full dynamic tension capacity of the reinforcing steel and they frame into relatively heavy perimeter girders. For demonstration purposes, they will be assumed to develop tension membrane response in this example. The beams will also be designed considering a Type II cross-section at deflections greater than 2 degrees of support rotation, as is often required for DoD blast design manuals. For the concrete, the compression strength f'_c = 4000 psi, and the minimum reinforcing steel yield strength f_y = 60 ksi.

Analysis Parameters:
- Span L = 25 ft
- Spacing B = 7 ft
- Fixed-Fixed supports
- Include Tension Membrane and Type II cross section
- Cross-sectional dimensions of joist: H = 12 in, W = 12 in
- Reinforcement of 3 #5 on the bottom and 2 #6 on the top. Also, stirrups throughout span.
- Joist supports a 4 in. slab.
- f'_c = 4000 psi
- f_y = 60 ksi
- LLOP for secondary type component is required

Solution

On the “Intro” worksheet area (Figure 1), select “One-Way Reinforced Concrete Beam or Beam Column” and English units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Span, L = 25 ft
- Spacing, B = 7 ft
- Set Boundary Conditions to “Fixed-Fixed, Uniformly Loaded”
- Select “Flexural and Tension Membrane” and “Include Type II Section” for Response Type

- On the Structural & Material Properties input box:
    - Section Height, H = 12 in
    - Section Width, W = 12 in
    - Positive Moment Reinf. Steel, Asp: Inbound = 0.93 in^2 (bottom face steel), Rebound = 0.88 in^2 (top face steel)
    - Negative Moment Reinf. Steel, Asn: Inbound = 0.88 in^2 (top face steel), Rebound = 0.93 in^2 (bottom face steel).
      Note: This assumes the bottom steel is fully developed into the support. If this is not true, enter zero for the rebound negative moment reinforcing steel.
    - Distance of Cover to Center of Bars = 2 in, top and bottom
    - Supported Weight = 150 pcf x 4 in (thickness of supported slab) = 50 psf
    - Concrete Density = 150 pcf
    - Compressive Strength = 4000 psi
    - Select Grade 60 for steel reinforcement
- Select “Manual Input” under Blast Load Input Type, and “In direction of blast load” under Gravity Displacement
- Enter the appropriate values for the applied pressure history shown above in the Pressure-Time input table
- Select “Flexure-shear reinforcing & TM” and “LLOP/Secondary-NS” under Response Criteria
- Select “No Dynamic Axial Load” under Dynamic Axial Load
- Select a time step for the analysis equal to the minimum recommended time step

The input screen will appear as shown on the next page.

Reinforced Concrete Beam or Beam-Column

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

Span, L:		25.00	ft
Spacing, B:		7.00	ft
Boundary Conditions:	Fixed-Fixed, Uniformly Loaded		
Response Type:	Flexural and Tension Membrane	Include Type II Section	

Structural & Material Properties

Section Height, H:		12.00	in
Section Width, W:		12.00	in
Reinforcing Steel Areas	Inbound	Rebound	
Positive Moment Reinf. Steel, Asp:	0.93	0.88	in^2
Negative Moment Reinf. Steel, Asn:	0.88	0.93	in^2
Distance of Cover to Center of Bars: d_c	(see diagram below)		
Non-Loaded Side:		2.00	in
Loaded Side:		2.00	in
Loaded Area Factor - Enter 1.0 for Uniform Load		1	
Supported Weight, w:		50.00	psf
Concrete Density, γ:		150	lb/ft^3
Concrete Compressive Strength, f'_c:		4000	psi
Concrete Static Strength Increase Factor (>=1):		1.00	
Concrete Dynamic Compr. Increase Factor (>=1):		1.19	
Concrete Dynamic Compr. Strength, f'_{dc}:		4,760	psi
Concrete Elastic Modulus, E_c:		3,834,254	psi
Select Reinforcement:	A615, A616, A706 (All Gr. 60)		
Reinf. Steel Yield Strength, f_y:		60,000	psi
Reinf. Steel Ultimate Strength, f_u:	Click for User Defined Steel	90,000	psi
Static Strength Increase Factor:		1.1	
Dynamic Increase Factor:		1.17	
Dynamic Reinf. Steel Yield Stress, f_{ds}:		77,220	psi
Reinf. Steel Elastic Modulus, E_s:		29000000	psi
No Dynamic Axial Load	[1] Static Axial Load, P:	0	lb
Leave blank for No Dynamic Axial Load			ft

*See Cell Q37 for Reinf. Steel Diagram

Calculated Properties

	No Axial Load	With Axial Load	
Rebound Positive Moment Capacity, M_p:	631982	631982	lb-in
Inbound Positive Moment Capacity, M_p:	665035	665035	lb-in
Inbound Positive Reinforcement Ratio, ρ_p:	0.0078		
Rebound Negative Moment Capacity, M_p:	665035	665035	lb-in
Inbound Negative Moment Capacity, M_p:	631982	631982	lb-in
Inbound Negative Reinforcement Ratio, ρ_n:	0.0073		

Blast Load Input Type

Manual input

Gravity Displacement

In direction of blast load

Pressure-Time Input

Time (ms)	Pressure (psi)
0	21.5
20	0
25	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (lbs TNT)	R (ft)

Blast Load Phase

Positive phase only

Charge Weight Load Type

Reflected without Clearing

Parameters for Reflected Loads

Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Applied Blast Input File Not Selected

See All COE Response Criteria

Response Criteria

Flexure-shear reinforcing & TM

LOP/Type	LLOP/Secondary-NS
θ (deg)	**µ**
12	N/A

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F constant =	0.14	0.12
R constant =	0.36	0.38

Solution Control

Inbound Natural Period:	144.14	ms
Rebound Natural Period:	144.14	ms
Max Recommended Time Step:	0.40	ms
Time Step:	0.14	ms
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	1283.7	1283.7	$psi\text{-}ms^2/in$
Load-Mass Factors, K_{LM}			
K_{LM1}	0.77	0.77	
K_{LM2}	0.66	0.66	
K_{LM3}	0.66	0.66	
K_{LM4}	0.66	0.66	
K_{LM5}	0.66	0.66	
Stiffness, K			
K_1	1.88	1.88	psi/in
K_2	0.00	0.00	psi/in
K_3	-0.42	-0.42	psi/in
K_4	0.00	0.00	psi/in
K_5	0.09	0.09	psi/in
Resistance, R			
R_1	1.37	-1.37	psi
R_2	1.37	-1.37	psi
R_3	1.15	-1.15	psi
R_4	1.15	-1.15	psi

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the beam. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below.

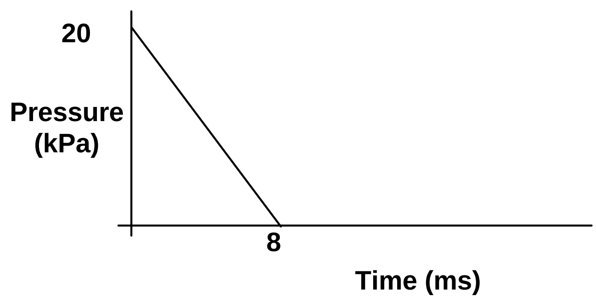
For this problem, the calculated maximum dynamic displacement is 24.48 in. This corresponds to a ductility ratio of 33.5 and a support rotation of 9.27 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the performance criteria for this type of component and analysis are only based on support rotation.

Under the Results Summary, SBEDS displays the calculated reactions and the shear capacity provided by the concrete portion of the beam. For this example, the concrete shear capacity is adequate at distance d from the support as indicated by the "Shear is OK" message. Therefore, stirrups are only required to laterally brace the compression face reinforcing steel. This requirement is addressed in DoD blast design manuals.

Results Summary				
θ_{max} = 9.27 deg.	Design Criteria:	LLOP/Secondary-NS		
μ = 33.50	Response OK compared to input design criteria			
X_{max} Inbound =	24.48 in	at time =	186.76 msec	
X_{min} Rebound =	0.26 in	at time =	0.00 msec	
R_{max} =	2.11 psi	at time =	186.76 msec	
R_{min} =	-1.11 psi	at time =	258.86 msec	
Shortest Yield Line Distance to Determine θ:			150.0 in	
Equivalent Static Reactions*				
Peak Reactions Based on Ultimate Flexural Resistance: Vu				
Vu at right support =			17,294 lb	
Vu at left support =			17,294 lb	
Maximum Vu at distance d from support =			16,141 lb	
Concrete Shear Capacity				
Direct Shear Capacity, (monolithic joint) $V_{c,direct}$ =			91392.0 lb	
Diagonal Shear Capacity, $V_{c,diag}$ =			16558.3 lb	
Tensile steel depth for shear calculations, d:			10.0 in	
Results based on Max Shear Region				
At support:		Stirrups Required		
At distance d from support:		Shear is OK		
Required Stirrups based on Max Shear Region, $A_{v,req}$ **				
For critical section @ support, A_{v,req_s};			0.0010 in²/in	
For critical section at d, A_{v,req_d};			0.0000 in²/in	
* Based on larger of inbound and rebound ultimate flexural resistance, not including tension or compression membrane.				
**Multiply Av values by flexural bar spacing and stirrup spacing to get stirrup area				

Example 7B: One-Way Reinforced Concrete Beam or Beam Column (Metric)

Analyze the response of a 4 m tall perimeter building column to the effects of an applied blast load as defined below.



The columns in this building are spaced at 7 m O.C. The columns are square with outside dimensions of 460 mm x 460 mm. Steel reinforcement consists of four 19 mm longitudinal bars (Gr. 415) and stirrups. Concrete cover distance to the longitudinal reinforcing steel is 50 mm all around. The estimated axial load acting on the perimeter columns is 1.0E+6 N calculated as recommended in PDC TR-06-08. There is a 150 mm concrete wall slab that is supported by a steel girt that frames into the columns at midspan. The wall spans between the girt and the slabs above and below so that the load from the slab is transferred to the columns only by the girt. Assume fixed-simple supports for the column, and provide a LLOP for primary type components as the Response Criteria. (The column is assumed to be pinned at the base and it is continuous over the second floor, so that symmetry of blast load above and below the floor level will cause a zero rotation support condition at the top of the column.) The concrete compression strength f'_c = 28 MPa. Lateral ties will be provided to support the longitudinal steel acting as compression steel, which affects the applicable response criteria category. This is a first floor column (maximum compression load) that supports several floors above and an open web joist roof system identical to Example 3A.

Analysis Parameters:

- Column span, L = 4 m
- Column spacing, B = 7 m
- Cross-sectional dimensions: H = 460 mm, W = 460 mm
- Fixed-simple column supports
- Reinforced with two 19 mm bars (Gr. 415) at each face, clear cover = 50 mm. It is assumed that these bars are continuous over the column span.
- f'_c = 28 MPa
- Static axial load, P = 1000000 N not including roof static load
- LLOP for primary type component is required
- Dynamic axial load from open web joist roof system

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way Reinforced Concrete Beam or Beam Column" and Metric units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Span, L = 4000 mm
- Spacing, B = 7000 mm
- Set Boundary Conditions to "Fixed-Simple, Conc. Load at Mid-Span"
- Select "Flexural only" and "Type I Cross-Section" for Response Type
- On the Structural & Material Properties input box:
    - Section Height, H = 460 mm
    - Section Width, W = 460 mm
    - Positive Moment Reinf. Steel, Asp = 568 mm^2 (Inbound and Rebound)
    - Negative Moment Reinf. Steel, Asn = 568 mm^2 (Inbound and Rebound)
    - Distance of Cover to Center of Bars = 50 mm, all around
    - Set Loaded area factor to 0.5 to account for fact that only the middle half of the wall slab transfers load into the girt that loads the column. The top and bottom quarter spans of the wall transfer blast load directly into the floor diaphragms.
    - Supported Weight = 2403 kg/m^3 x 150 mm (thickness of supported wall slab) = 360.5 kg/m^2. Conservatively assume that 20% of this value (72 kg/m^2) actually deflects with the column. Some of the wall slab is supported by the floor diaphragms, and therefore deflects very little, and the rest deflects primarily with girt, which varies somewhat from the column deflection.
    - Concrete Density = 2403 kg/m^3
    - Compressive Strength = 28 MPa
    - Select Grade 415 for steel reinforcement
    - Enter 1.0E+6 N for Static Axial Load for compression and P-delta effects (Note that this does not include any roof static load since that is included in the Dynamic Axial Load that will also be input for this example)
- Select "Manual Input" under Blast Load Input Type, and "none (vertical component)" under Gravity Displacement
- Enter the appropriate values in the Pressure-Time input table
- Select "F&C shear reinforcement no TM" and "MLOP/Primary" under Response Criteria. The lateral ties in the column will act to confine the longitudinal reinforcing steel acting as compression flexural steel, which is the intent of the shear reinforcement requirement in this case.
- Select "Dynamic Axial Load per Unit Width" and then use the browser to select the file. This is the same dynamic axial load input file read into Example 5A converted into the appropriate metric units as specified in Appendix A of the SBEDS User's Guide.
- Select a time step for the analysis equal or less than the recommended value in the Solution Control input box in SBEDS.

The input screen will appear as shown next.

Reinforced Concrete Beam or Beam-Column

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

Span, L:		4000	mm
Spacing, B:		7000	mm
Boundary Conditions:	Fixed-Simple, Conc. Load at Midspan		
Response Type:	Flexural Only	Type I Cross Section	

Structural & Material Properties

	Inbound	Rebound	
Section Height, H:		460	mm
Section Width, W:		460	mm
Reinforcing Steel Areas	Inbound	Rebound	
Positive Moment Reinf. Steel, Asp:	568	568	mm^2
Negative Moment Reinf. Steel, Asn:	568	568	mm^2
Distance of Cover to Center of Bars: d	(see diagram below)		
Non-Loaded Side:		50	mm
Loaded Side:		50	mm
Loaded Area Factor Applied to L*B, Af:(Af<=1)		0.5	
Supported Weight, w:		72.1	kg/m^2
Concrete Density, γ:		2403	kg/m^3
Concrete Compressive Strength, f'_c:		28	MPa
Concrete Static Strength Increase Factor (>=1):		1.0	
Concrete Dynamic Compr. Increase Factor (>=1):		1.19	
Concrete Dynamic Compr. Strength, f'_{dc}:		33	MPa
Concrete Elastic Modulus, E_c:		26,803	MPa
Select Reinforcement:	A615, A616, A706 (All Gr. 415)		
Reinf. Steel Yield Strength, f_y:		415	MPa
Reinf. Steel Ultimate Strength, f_u:	Click for User Defined Steel	620	MPa
Static Strength Increase Factor:		1.1	
Dynamic Increase Factor:		1.17	
Dynamic Reinf. Steel Yield Stress, f_{ds}:		534	MPa
Reinf. Steel Elastic Modulus, E_s:		200,000	MPa
No Dynamic Axial Load	* Static Axial Load, P:	1000000	N
Leave blank for No Dynamic Axial Load			mm

*See Cell Q37 for Reinf. Steel Diagram

Calculated Properties

	No Axial Load	With Axial Load	
Rebound Positive Moment Capacity, M_p:	120850230	214317287	N-mm
Inbound Positive Moment Capacity, M_p:	120850230	214317287	N-mm
Inbound Positive Reinforcement Ratio, ρ_p:	0.0030		
Rebound Negative Moment Capacity, M_n:	120850230	214317287	N-mm
Inbound Negative Moment Capacity, M_n:	120850230	214317287	N-mm
Inbound Negative Reinforcement Ratio, ρ_n:	0.0030		

Blast Load Input Type

Manual input

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (kPa)
0	20
8	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (kg TNT)	R (m)

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected without Clearing

Parameters for Reflected Loads

Wall Height (m)[1]
Wall Width (m)[1]
Incidence Angle[2]

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Applied Blast Input File Not Selected

Response Criteria

See All COE Response Criteria

F&C-shear reinforcing, no TM

LOP/Type	MLOP/Primary
θ (deg)	μ
N/A	1

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (simple support) =	-0.18	-0.25
R (simple support) =	0.50	0.58
F (fixed support) =	-0.28	-0.25
R (fixed support) =	0.97	0.92

Solution Control

Inbound Natural Period:	18.98	ms
Rebound Natural Period:	18.98	ms
Max Recommended Time Step:	0.05	ms
Time Step:	0.09	ms
% of Critical Damping:	0	%
Initial Velocity:	0	mm/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	144.74	144.74	kg/m^2
Load-Mass Factors, K_{LM}			
K_{LM1}	0.43	0.43	
K_{LM2}	0.49	0.49	
K_{LM3}	0.33	0.33	
K_{LM4}	0.33	0.33	
K_{LM5}	0.33	0.33	
Stiffness, K			
K_1	6.82	6.82	kPa/mm
K_2	3.06	3.06	kPa/mm
K_3	0.00	0.00	kPa/mm
K_4	0.00	0.00	kPa/mm
K_5	0.00	0.00	kPa/mm
Resistance, R			
R_1	20.41	-20.41	kPa
R_2	22.96	-22.96	kPa
R_3	22.96	-22.96	kPa
R_4	22.96	-22.96	kPa

After the input sheet is completed click the “Run SDOF” button at the top of the screen (See Figure 2) to calculate the dynamic response of the beam. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below.

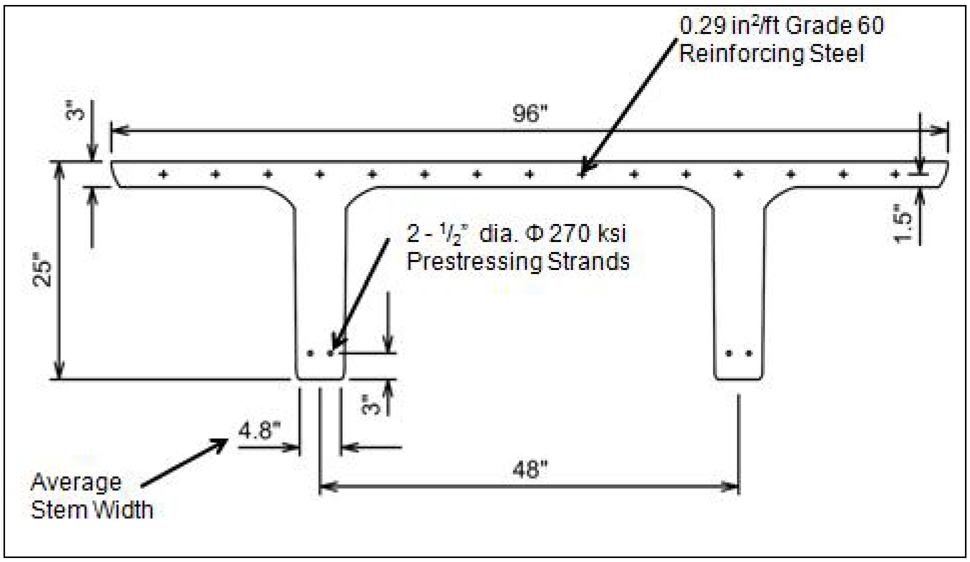
For this problem, the calculated maximum dynamic displacement is 3.2 mm. This corresponds to a ductility ratio of 0.95 and a support rotation of 0.09 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the performance criteria for this type of component and analysis are only based on ductility ratio.

Under the Results Summary, SBEDS displays the calculated reactions and the shear capacity provided by the concrete portion of the beam. For this example, the concrete shear capacity is adequate at distance d from the support as indicated by the “Shear is OK” message. Therefore, shear stirrups are not required.

Shear Based on Equivalent Static Reactions*			
θ_{max} =	0.09 deg.	Design Criteria:	MLOP/Primary
μ =	0.95	Response OK compared to input design criteria	
X_{max} Inbound =	3.24 mm	at time =	7.56 msec
X_{min} Rebound =	-2.95 mm	at time =	17.19 msec
R_{max} =	21.10 kPa	at time =	7.56 msec
R_{min} =	-20.70 kPa	at time =	17.19 msec
Shortest Yield Line Distance to Determine θ:			2000.0 mm
Equivalent Static Reactions*			
Peak Reactions Based on Ultimate Flexural Resistance: Vu			
Vu at fixed support =			221,818 N
Vu at simple support =			99,658 N
Maximum Vu at distance d from support =			176,346 N
Concrete Shear Capacity			
Direct Shear Capacity, (monolithic joint) $V_{c,direct}$ =			1005464.3 N
Diagonal Shear Capacity, $V_{c,diag}$ =			181444.1 N
Tensile steel depth for shear calculations, d:			410.0 mm
Results based on Max Shear Region			
At support:		Stirrups Required	
At distance d from support:		Shear is OK	
*Required Stirrups based on Max Shear Region, $A_{v,req}$ ** *			
For critical section @ support, A_{v,req_s}:			0.1844 mm²/mm²
For critical section at d, A_{v,req_d}:			0.0000 mm²/mm²
* Based on larger of inbound and rebound ultimate flexural resistance, not including tension or compression membrane.			
**Multiply Av values by flexural bar spacing and stirrup spacing to get stirrup area			

Example 8A: One-Way Prestressed Concrete Beam or Panel (English)

Analyze the response of a 40 ft long pre-stressed concrete Tee-beam illustrated below to the effects of side-on blast load from 650 lbs of TNT at 50 ft of standoff. Two 0.5 in diameter bonded Grade 270 pre-stressing strands are used for pre-tensioning with a clear cover distance of 3 in at midspan. The beams are 25 in deep (including a 3 in slab) and have 4.8 in stems and spaced at 48 in on center. The slab is reinforced at mid-thickness with welded wire fabric (WWF) having a reinforcing steel area equivalent to 0.29 in^2 @ 12 in. A LLOP is required for this secondary-type component. The concrete compression strength (f'_c) is 5000 psi.



Analysis Parameters:
- Span, L = 40 f
- Beam spacing, B = 4 ft
- Beam uses two 0.5 in Grade 270 strands of prestressing steel with a clear cover = 3 in
- Beam web depth = 25 in, Beam web width = 4.8 in.
- 3 in slab reinforced with 0.29 in^2 @ 12 in on center of WWF
- LLOP for secondary type components
- f'_c=5000 psi
- Simple supports
- 650 lb of TNT @ 50 ft. Only side-on pressure loads the beam.

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way Prestressed Concrete Beam or Panel" and English units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Span, L = 40 ft
- Set Boundary Conditions to "One-Way, Simple-Simple, Uniformly Loaded"
- Select "BEAM w/Bonded Tendons – Flexural Response" for Response Type
- On the Structural & Material Properties input box:
  - Beam Spacing, B = 4 ft
  - Section Height, H = 25 in (include slab thickness)

- o Beam flange, W_f = 48 in
- o Beam web width = 4.8 in
- o Beam flange thickness T_f = 3 in
- o Positive Moment prestressed steel, App = 0.31 in^2
- o Positive Moment non pre-stressed steel, Asp (Rebound) = 1.16 in^2 (0.29 in^2 per foot WWF at mid-height in slab over 4 ft beam spacing)
- o Prestressing steel cover, dp = 3 in.
- o Conventional reinforcing steel cover, dc = 1.5 in (from the top)
- o Concrete density = 150 pcf (Typical value for reinforced concrete)
- o Compressive Strength = 5000 psi
- o Concrete static strength increase factor = 1.0
- o Concrete dynamic increase factor = 1.19
- o Select Grade 270 for pre-stressing steel
- o Select Grade A82 for welded wire steel reinforcement

- Select “Charge weight and standoff” under Blast Load Input Type, and “In direction of blast load” under Gravity Displacement
- Enter charge weight and standoff
- Select “Positive phase” and “Side-on” under blast load phase and charge weight load type, respectively.
- Select “wp <0.15” and “LLOP/Secondary-NS” under Response Criteria. (Note that cell H46 shows that wp,the prestressing steel reinforcement index, is equal to 0.1 in the input values.)
- Select In the Direction of Blast Load as the Gravity Displacement
- Select a time step for the analysis based on recommended time step

The input screen will appear as shown on the next page.

Prestressed Concrete Beam or Panel

User Info: Fill in Yellow Cells, See Note Below for White Cells			
Span Length, L:		40.0	ft
Leave Input Blank for One-Way Response			
Boundary Conditions:	One-Way: Simple-Simple, Uniformly Loaded		
Component Type/Response Type:	BEAM w/ Bonded Tendons - Flexural Response		
Structural & Material Properties (See diagram below)			
Beam Spacing, B;		48.0	in
Beam Height, H;		25.0	in
Beam Flange Width, Wf;		48.0	in
Beam Web Width, Ww;		4.8	in
Beam Flange Thickness, Tf;		3.0	in
*Prestressed Steel Areas:**	Inbound	No Input Req'd	
Positive Moment Prestressed Steel, App:	0.31	0.00	in^2
Leave Blank for Simple Supports	0.00	0.00	in^2
*Nonprestressed Steel Areas:**	Inbound	Rebound	
Positive Moment Nonprestressed Steel, Asp:	0.00	1.16	in^2
Leave Blank for Simple Supports	0.00	0.00	in^2
*Distance of Cover to Center of Bars:**	Non-Loaded Side	Loaded Side	
Prestressing Steel, dc_p:	3.00	0.00	in
Conventional Reinforcing Steel, d_c:	0.00	1.50	in
Supported Weight, w:		0	psf
Concrete Density, γ:		150	lb/ft^3
Concrete Compressive Strength, f'_c:		5000	psi
Concrete Static Strength Increase Factor (>=1):		1.00	
Concrete Dynamic Compr. Increase Factor (>=1):		1.19	
Concrete Dynamic Compr. Strength, f'_{dc}:		5,950	psi
Concrete Elastic Modulus, E_c:		4,286,826	psi
Select Prestressing Steel Type:	ASTM A 416 Grade 270		
Effective Prestressing Steel Yield Strength, f_{ps}:		268113	psi
Select Conventional Reinforcement:	A82, A496 (All Gr. 70) Welded Wire Fabric		
Conventional Reinf. Steel Yield Strength, fy:	Click for User Defined Steel	70,000	psi
Conventional Reinf. Steel Ultimate Strength, f_u:		80,000	psi
Conventional Steel Static Strength Increase Factor:		1.00	
Conventional Steel Dynamic Increase Factor:		1.10	
Dynamic Conventional Reinf. Steel Yield Stress, f_{ds}:		77,000	psi
Reinf. Steel Elastic Modulus, E_s:		29000000	psi
Calculated Properties			
Inbound Positive Moment Capacity, Mp:		37314	lb-in/in

Blast Load Input Type
Charge weight and standoff
Gravity Displacement
In direction of blast load

Pressure-Time Input	
Time	Pressure
(ms)	(psi)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

*See Cell Q34 for Reinf. Steel Diagram

Charge Weight and Standoff	
W	R
(lbs TNT)	(ft)
650	50
Blast Load Phase	
Positive phase only	
Charge Weight Load Type	
Side-on	
Parameters for Reflected Loads	
Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[1]	

See notes under error messages

Load file name	
Applied Blast Input File Not Selected	
Response Criteria*	
wp < 0.15	
LOP/Type	LLOP/Secondary-NS
θ (deg)	μ
2	N/A

See All COE Response Criteria

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

Solution Control		
Inbound Natural Period:	193.25	ms
Rebound Natural Period:	193.25	ms
Max Recommended Time Step:	0.25	ms
Time Step:	0.25	ms
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties			
Property	Inbound	Rebound	Units
Mass, M	1168.2	1168.2	$psi\text{-}ms^2/in$
Load-Mass Factors, K_{LM}			
Elastic	0.78	0.78	
Elastic-Plastic	0.78	0.78	
Plastic	0.66	0.66	
Stiffness, K			
Elastic	0.96	0.96	psi/in
Elastic-Plastic	0.96	0.96	psi/in
Resistance, R			
Elastic	1.30	-1.29	psi
Plastic	1.30	-1.29	psi
Yield Displacement, x			
x1	1.35	-1.34	in
x2	1.35	-1.34	in
Equiv Yield Defl., X_E	1.35	-1.34	in

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the beam. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below.

For this problem, the calculated maximum dynamic displacement is 8.03 in. This corresponds to a ductility ratio of 5.97 and a support rotation of 1.92 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the response criteria for this type of component at this level of protection are only based on support rotation.

Under the Results Summary, SBEDS displays the calculated reactions and the shear capacity provided by the concrete portion of the beam. For this example, the concrete shear capacity is adequate as indicated by the "Shear is OK" message. Therefore, stirrups are not required.

Results Summary					
θ_{max} =	1.92 deg.	Design Criteria:	LLOP/Secondary-NS		
μ =	5.97	Response OK compared to input design criteria			
X_{max} Inbound =	8.03 in	at time =	120.75 msec		
X_{min} Rebound =	0.47 in	at time =	0.00 msec		
R_{max} =	1.30 psi	at time =	120.75 msec		
R_{min} =	-0.39 psi	at time =	217.50 msec		
Shortest Yield Line Distance to Determine θ:			240.0 in		
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
Vu at right support =			14,925.6	lb	
Vu at left support =			14,925.6	lb	
Maximum Vu at distance d from support *** =			13,557.4	lb	
Concrete Shear Capacity (No prestress assumed acting at ultimate response)					
Direct Shear Capacity (monolithic joint), $V_{c,direct}$ =			100531.2	lb	
Diagonal Shear Capacity, $V_{c,diag}$ =			16291.2	lb	
Tensile steel depth for shear calculations, d:			22.0	in	
*Results based on Max Shear Region****					
At support:		Shear is OK			
At distance d from support:		Shear is OK			
*Required Stirrups based on Max Shear Region, A_v ** *					
For critical section @ support, A_{v,req_s}:			0.0000	in^2/in	
For critical section at d, A_{v,req_d}:			0.0000	in^2/in	
* Based on larger of inbound and rebound ultimate flexural resistance.					
**Multiply Av values by stirrup spacing to get stirrup area					

Example 8B: One-Way Prestressed Concrete Beam or Panel (Metric)

This example is the metric equivalent of Example 8A, except that the blast load will be generated in the CONWEP computer code (which is distributed by the U.S. government) rather than SBEDS. Therefore, analyze the response of a 12.2 m long "T-shaped" pre-stressed concrete beam to the side-on blast load from 294.8 kg of TNT at 15.2 m of standoff. In this case, the standoff is measured to midspan on the beam. Generate the pressure-history using CONWEP, use the plot option in CONWEP for the side-on pressure-history (which will automatically use the DPLOT software to plot the pressure-history) and save the pressure-history out of DPLOT into an ASCII file onto the computer hard drive. The beam has two 12.5 mm diameter bonded Grade 270 pre-stressing strands with a clear cover distance of 75 mm at midspan. The beams are 635 mm deep (including a 75 mm slab) with 122 mm wide stems that are spaced at 1.2 m on center. The slab is reinforced at mid-thickness with welded wire fabric (WWF) having a steel area equivalent to 0.61 mm^2/ mm of slab width. A LLOP must be provided with this secondary type component. The concrete compression strength (f'_c) is 34.5 MPa.

Analysis Parameters:

- Span, L = 12.2 m
- Beam spacing, B = 1.2 m
- Two 12.5 mm Grade 270 bonded prestressing strands with 75 mm clear cover at midspan
- Beam depth = 635 mm, Beam web = 122 mm.
- Simple supports
- Spacing 1.2 m
- 75 mm slab reinforced with 0.61 mm^2/mm of WWF at midthickness
- LLOP for secondary type components
- f'_c= 34.5 MPa
- Side-on blast load from 294 kg of TNT @ 15.2 m. Pressure-history generated with CONWEP, saved as ASCII file, read into SBEDS

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way Prestressed Concrete Beam or Panel" and Metric units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Span, L = 12200 mm
- Set Boundary Conditions to "One-Way, Simple-Simple, Uniformly Loaded"
- Select "BEAM w/Bonded Tendons – Flexural Response" for Response Type
- On the Structural & Material Properties input box:
    - Beam Spacing, B = 1200 mm
    - Section Height, H = 635 mm (include slab thickness)
    - Beam flange, Wf = 1200 mm (beam spacing controls)
    - Beam web width = 122 mm
    - Beam flange thickness Tf = 75mm
    - Positive Moment pre-stressed steel, App = 200 mm^2
    - Positive Moment non pre-stressed steel, Asp (Rebound) = 748 mm^2 (WWF at mid-height in slab) based on 0.61 mm^2/mm over 1.2 m beam spacing
    - Prestressing steel cover, dp = 75 mm
    - Conventional reinforcing steel cover, dc = 37.5 (from the top)

  - Concrete density = 2403 kg/ m^3 ((Typical value for reinforced concrete)
  - Compressive Strength = 34.5 MPa
  - Concrete static strength increase factor = 1.0
  - Concrete dynamic increase factor = 1.19
  - Select ASTM A 416 Grade 1860 for prestressing steel
  - Select Grade A82 welded wire fabric for conventional steel reinforcement
- Select "Pressure-time history file" under Blast Load Input Type, and select the ASCII file saved in CONWEP to read it into SBEDS.
- Select "wp <0.15" and "LLOP/Secondary-NS" under Response Criteria. (Note that cell H46 shows that wp ,the prestressing steel reinforcement index, is equal to 0.1 for in the input values.)
- Select In the Direction of Blast Load as the Gravity Displacement
- Select a time step for the analysis based on recommended time step

The input screen will appear as shown on the next page.

Prestressed Concrete Beam or Panel

User Info: Fill in Yellow Cells, See Note Below for White Cells			
Span Length, L:		12200	mm
Leave Input Blank for One-Way Response			
Boundary Conditions:	One-Way: Simple-Simple, Uniformly Loaded		
Component Type/Response Type:	BEAM w/ Bonded Tendons - Flexural Response		

Structural & Material Properties (See diagram below)			
Beam Spacing, B;		1200	mm
Beam Height, H;		635	mm
Beam Flange Width, Wf;		1200	mm
Beam Web Width, Ww;		122	mm
Beam Flange Thickness, Tf;		75	mm
*Prestressed Steel Areas:**	Inbound	No Input Req'd	
Positive Moment Prestressed Steel, App:	200.00	0.00	mm^2
Leave Blank for Simple Supports	0.00	0.00	mm^2
*Nonprestressed Steel Areas:**	Inbound	Rebound	
Positive Moment Nonprestressed Steel, Asp:	0.00	748.00	mm^2
Leave Blank for Simple Supports	0.00	0.00	mm^2
*Distance of Cover to Center of Bars:**	Non-Loaded Side	Loaded Side	
Prestressing Steel, d_p:	75.00	0.00	mm
Conventional Reinforcing Steel, d_c:	0.00	37.50	mm
Supported Weight, w:		0.00	kg/m^2
Concrete Density, γ:		2403.00	kg/m^3
Concrete Compressive Strength, f'_c:		34.50	MPa
Concrete Static Strength Increase Factor (>=1):		1.00	
Concrete Dynamic Compr. Increase Factor (>=1):		1.19	
Concrete Dynamic Compr. Strength, f'_{dc}:		41	MPa
Concrete Elastic Modulus, E_c:		29,751	MPa
Select Prestressing Steel Type:	ASTM A 416 Grade 1860		
Effective Prestressing Steel Yield Strength, f_{ps}:		1847	MPa
Select Conventional Reinforcement:	A82, A496 (All Gr. 482) Welded Wire Fabri		
Conventional Reinf. Steel Yield Strength, fy:	Click for User Defined Steel	482	MPa
Conventional Reinf. Steel Ultimate Strength, f_u:		550	MPa
Conventional Steel Static Strength Increase Factor:		1	
Conventional Steel Dynamic Increase Factor:		1.1	
Dynamic Conventional Reinf. Steel Yield Stress, f_{ds}:		530	MPa
Reinf. Steel Elastic Modulus, E_s:		200000	MPa

Calculated Properties		
Inbound Positive Moment Capacity, Mp:	170998	N-mm/mm

Blast Load Input Type
Pressure-time history file
Gravity Displacement
In direction of blast load

Pressure-Time Input	
Time	Pressure
(ms)	(kPa)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

*See Cell Q34 for Reinf. Steel Diagram

Charge Weight and Standoff	
W	R
(kg TNT)	(m)
Blast Load Phase	
Positive phase only	
Charge Weight Load Type	
Side-on	
Parameters for Reflected Loads	
Wall Height (m)[1]	
Wall Width (m)[1]	
Incidence Angle[2]	

See notes under error messages

Load file name	
8B load from 8A conwepdlplot.txt	
Response Criteria*	
wp < 0.15	
LOP/Type	LLOP/Secondary -NS
θ (deg)	μ
2	N/A

See All COE Response Criteria

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

Solution Control		
Inbound Natural Period:	191.83	ms
Rebound Natural Period:	191.83	ms
Max Recommended Time Step:	0.01	ms
Time Step:	0.48	ms
% of Critical Damping:	0	%
Initial Velocity:	0	mm/ms

SDOF Properties			
Property	Inbound	Rebound	Units
Mass, M	317.0	317.0	kg/m^2
Load-Mass Factors, K_{LM}			
Elastic	0.78	0.78	
Elastic-Plastic	0.78	0.78	
Plastic	0.66	0.66	
Stiffness, K			
Elastic	0.27	0.27	kPa/mm
Elastic-Plastic	0.27	0.27	kPa/mm
Resistance, R			
Elastic	9.19	-9.02	kPa
Plastic	9.19	-9.02	kPa
Yield Displacement, x			
x1	34.64	-33.98	mm
x2	34.64	-33.98	mm
Equiv Yield Defl., X_E	34.64	-33.98	mm

After the input sheet is completed click the “Run SDOF” button at the top of the screen (See Figure 2) to calculate the dynamic response of the beam. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below. For this problem, the calculated maximum dynamic displacement is 199.2 mm. This corresponds to a ductility ratio of 5.75 and a support rotation of 1.87 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the performance criteria for this type of component at this level of protection are only based on support rotation.

Under the Results Summary, SBEDS displays the calculated reactions and the shear capacity provided by the concrete portion of the beam. For this example, the concrete shear capacity is adequate as indicated by the “Shear is OK” message. Therefore, shear stirrups are not required.

Results Summary					
θ_{max} =	1.87 deg.	Design Criteria:		LLOP/Secondary-NS	
μ =	5.75	Response OK compared to input design criteria			
X_{max} Inbound =	199.22 mm	at time =		116.64 msec	
X_{min} Rebound =	11.72 mm	at time =		0.00 msec	
R_{max} =	9.19 kPa	at time =		116.64 msec	
R_{min} =	-2.96 kPa	at time =		212.64 msec	
Shortest Yield Line Distance to Determine θ:				6100.0 mm	
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
Vu at right support =				67,278.1	N
Vu at left support =				67,278.1	N
Maximum Vu at distance d from support *** =				61,101.7	N
Concrete Shear Capacity (No prestress assumed acting at ultimate response)					
Direct Shear Capacity (monolithic joint), $V_{c,direct}$ =				448780.4	N
Diagonal Shear Capacity, $V_{c,diag}$ =				72959.1	N
Tensile steel depth for shear calculations, d:				560.0	mm
*Results based on Max Shear Region****					
At support:		Shear is OK			
At distance d from support:		Shear is OK			
*Required Stirrups based on Max Shear Region, A_v ***					
For critical section @ support, A_{v,req_s}:				0.0000	mm^2/mm
For critical section at d, A_{v,req_d}:				0.0000	mm^2/mm
* Based on larger of inbound and rebound ultimate flexural resistance.					
**Multiply Av values by stirrup spacing to get stirrup area					

Example 9A: One-Way or Two-Way Reinforced Masonry (English)

Analyze the response of a 12 ft tall, 8 in thick lightweight reinforced CMU wall to the effects of 980 lbs of TNT at 100 ft of standoff. The wall is on the side of the building not facing the explosive source, therefore it is subject to side-on blast pressure. Negative phase blast load will be included in the analysis. The CMU wall is reinforced with #5 bars at 16 in placed at mid-thickness. Only the reinforced cells are grouted. The wall has 4 ft wide by 5 ft high blast resistant windows at 8 ft spacing at midheight. The wall must provide LLOP as a secondary type component. The masonry compressive prism strength (f'_m) is 1500 psi. The reinforcing steel yield strength (f_y) is 60 ksi.

Analysis Parameters:

- Lightweight CMU
- Span, L = 12 ft
- Thickness = 8 in
- Reinforced with #5 bars at 16 in. O.C. Only the reinforced cells are grouted.
- Typical loaded wall width = 8 ft including 4 ft wide window
- LLOP of secondary type components
- Positive and negative phase side-on blast load from 980 lbs of TNT at 100 ft of standoff.
- f'_m = 1500 psi, f_y = 60 ksi

Solution

On the “Intro” worksheet area (Figure 1), select “One-Way and Two-way Reinforced Masonry” and English units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Span, L = 12 ft
- Width Resisting Blast Load / Loaded Width; Bw = 0.5. This conservatively accounts for the window openings based on a 4 ft wall width resisting blast load within an 8 ft wall width loaded by blast. In reality, the framing of blast resistant windows is usually quite robust and transfers most of the window load into the wall nearer to the supports so that less moment is applied to the wall away from the window than assumed here. (Additional reinforcing would normally be provided at each side of the windows.)
- Select “One-Way: Simple-Simple, Uniformly Loaded”
- Set the Response Type to “Flexural Only” and “Type I Cross Section”
- On the Structural & Material Properties input box fill in cells as follows:
    - Total Wall Thickness, t = 7.625 in (actual thickness of a typical nominal 8 in CMU block)
    - Reinforcing Steel Spacing – Bars Spanning Parallel to L, b = 16 in.
    - Reinforcing Steel Areas – Positive Moment Steel parallel to L, Asp = 0.31 in^2
    - Distance of Cover to Center of Bars, dc – Non-Loaded Side Spanning Parallel to L = t/2 = 3.8125
    - Select “Light Weight CMU” for Masonry Type
    - Percent of Void Space Grouted = 50 % . Bar spacing is 16 in, so that only every other cell will be reinforced and grouted.
    - Masonry Compressive Strength, f'_m = 1500 psi
    - Masonry Dynamic Compr. Strength Increase Factor = 1.19 (Typical Value, see SBEDS user manual)

  - o Select Reinforcement = Grade 60
- Select “Charge weight and standoff” under Blast Load Input Type, and “None (vertical component)” under Gravity Displacement
- Enter charge weight and standoff
- Select “Positive and negative phase” and “Side-on” under Blast load phase and charge weight load type respectively
- Set the Response Criteria to “Flexure” and “LLOP/Secondary-NS”
- Select “No Dynamic Axial Load”
- On the Solution Control input box, select a time step for the analysis based on the recommended value.

After these steps, the input screen will look as shown on the next page.

One-Way and Two-Way Reinforced Masonry

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

Span Length, L:	12	ft
Width Resisting Blast Load / Loaded Width; Bw	0.5	Note: 0 < Bw <=1.0
BoundaryConditions:	One-Way: Simple-Simple, Uniformly Loaded	
Response Type:	Flexural Only	Type I Cross Section

Structural & Material Properties

Total Wall Thickness, T:	7.625	in
Resinforcing Steel Spacing (See diagram in cell R37 for diagram of steel input terms)		
Bars Spanning Parallel to L, b_L:	16	in
Not Used for One-Way Response	0	
Reinforcing Steel Areas *(Symmetric reinforcement assumed)		
Positive Moment Steel Parallel to L, AspL:	0.31	in^2
Leave Input Blank for One-Way Response	0	
Negative Moment Steel Parallel to L, AsnL: *	0.31	in^2
Leave Input Blank for One-Way Response		
Distance of Cover to Center of Bars: d *(Symmetric reinforcement assumed)		
Non-Loaded Side Spanning Parallel to L:	3.8125	in
Leave Input Blank for One-Way Response	0	
Loaded Side Spanning Parallel to L: *	3.8125	in
Leave Input Blank for One-Way Response		
Masonry Type:	Light Weight CMU	
Percent of Void Spaced Grouted	50	%
Supported Weight, w:	0	psf
Masonry Compressive Strength, f'm:	1,500	psi
Masonry Dynamic Compr. Increase Factor:	1.19	
Wall Self-Weight, W:	48.79	psf
Masonry Dynamic Compr. Strength, f'_{dm}:	1,785	psi
Masonry Elastic Modulus, E_m:	1,500,000	psi
Select Reinforcement:	A615, A616, A706 (All Gr. 60)	
Reinf. Steel Yield Strength, f_y:	60,000	psi
Reinf. Steel Ultimate Strength, f_u:	90,000	psi
Average Increase Factor:	1.1	
Dynamic Increase Factor:	1.17	
Dynamic Reinf. Steel Yield Stress, f_{ds}:	77,220	psi
Reinf. Steel Elastic Modulus, E_s:	29000000	psi
Axial Load Input:	No Dynamic Axial Load	
Static Axial Load; P': (Note: P>=0)	0	lb/in
Leave Input Blank for One-Way Response	0	ft

Click for User Defined Masonry

Click for User Defined Steel

See All COE Response Criteria for AT/FP

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time	Pressure
(ms)	(psi)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W	R
(lbs TNT)	(ft)
1400	100

Blast Load Phase: Positive and negative phase

Charge Weight Load Type: Side-on

Parameters for Reflected Loads

Wall Height (ft) [1]	
Wall Width (ft) [1]	
Incidence Angle [2]	

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Applied Blast Input File Not Selected

Response Criteria

Flexure

LOP/Type: LLOP/Secondary-NS

θ (deg)	μ
8	N/A

Dynamic Shear Factors

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

Solution Control

Inbound Natural Period:	78.14	ms
Rebound Natural Period:	78.14	ms
Max Recommended Time Step:	0.22	msec
Time Step:	0.2	msec
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	438.5	438.5	psi-ms²/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	2.21	2.21	psi/in
K_2	2.21	2.21	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	0.96	-0.96	psi
R_2	0.96	-0.96	psi
R_3	0.96	-0.96	psi
R_4	0.96	-0.96	psi

After the input sheet is completed click the “Run SDOF” button at the top of the screen (See Figure 2) to calculate the dynamic response of the beam. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below. For this problem, the calculated maximum dynamic displacement is 10.1 inches. This corresponds to a ductility ratio of 23.1 and a support rotation of 7.91 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the performance criteria for this type of component at this level of protection are only based on support rotation.

Under the Results Summary, SBEDS displays the calculated reactions and the shear capacity provided by the concrete portion of the beam. For this example, the concrete shear capacity is adequate as indicated by the “Shear is OK” message. Therefore, shear stirrups are not required. Note that SBEDS calculates the shear capacity assuming the full loaded width of the wall, including the wall area under openings, resists shear as stated in the notes of the Results Summary. If the opening extends near a support for the wall (i.e., nearer than roughly the 1/4 of the wall height) such that the shear loads cannot be distributed into the supports along the full loaded width, the user must reevaluate the shear capacity as stated in the notes of the Results Summary and compare to the calculated peak reaction loads. The total peak applied peak reaction load equals the peak reaction load calculated in SBEDS multiplied by the full input loaded width for the component.

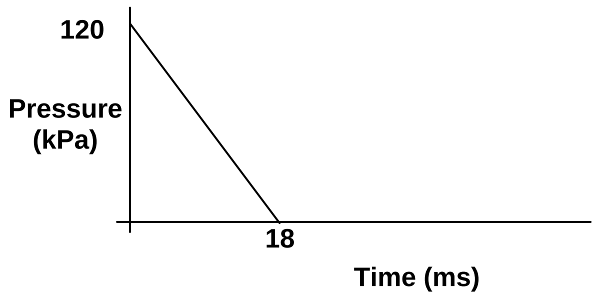
Results Summary					
θ_{max} =	7.91	deg.	Design Criteria:	LLOP/Secondary-NS	
μ =	23.10		Response OK compared to input design criteria		
X_{max} Inbound =	10.01	in	at time =	61.00	msec
X_{min} Rebound =	0.00	in	at time =	0.00	msec
R_{max} =	0.96	psi	at time =	61.00	msec
R_{min} =	-0.96	psi	at time =	160.40	msec
Shortest Yield Line Distance to Determine θ:				72.0	in

Equivalent Static Reactions*		
Peak Reactions Based on Ultimate Flexural Resistance: Vu		
Vu at right support*** =	69.0	lb/in
Vu at left support*** =	69.0	lb/in
Maximum Vu at distance d from support *** =	65.3	lb/in
Shear Capacity		
Diagonal Shear Capacity: $V_{c,diag}$ =	198.8	lb/in
Tensile steel depth for shear calculations, d:	3.8	in
Results based on Max Shear Region		
At support:	Shear is OK****	
At distance d from support:	Shear is OK****	
*Required Stirrups based on Max Shear Region, Av,req **,***		
Critical section @ support, A_{v,req_s}:	0.0000	in^2/in^2
Critical section at d, A_{v,req_d}:	0.0000	in^2/in^2

* Based only on larger of R_{max} or R_{min}, not including tension membrane or arching
**Multiply Av values by flexural bar spacing and stirrup spacing to get stirrup area
***Reactions act over entire loaded width
****Assumes entire loaded width resists shear. If openings reduce width of wall resisting shear, multiply shear capacity by Bw (cell D9) and manually check shear

Example 9B: One-Way or Two-Way Reinforced Masonry (Metric)

Analyze the response of a 3 m high by 5 m wide European block wall to a pressure load as defined below.



The wall is constructed with two wythes and a fully grouted annular space between them that is reinforced with 12.5 mm steel bars at 406 mm on center, each way. The total wall thickness is 305 mm, with steel ties between the wythes to cause the wall to act compositely. The load-bearing wall is simply supported on all four sides and is carrying a 200 N/mm equivalent static axial load acting in the vertical direction (along the 3 m dimension), calculated as recommended in PDC TR-08-06 to include the effects of dynamic reaction loading from roof components. The wall must provide a LLOP for primary type components. The masonry compressive prism strength (f'_m) is 10.50 MPa. The reinforcing steel yield strength (f_y) is 415 MPa.

Analysis Parameters:

- Two-way European block wall
- L = 5 m and H = 3 m
- Thickness = 305 mm
- Fully-grouted with 12.5 mm bars at 406 mm on center each way placed at mid-thickness
- LLOP for primary type components
- f'_m = 10.5 MPa, f_y = 415 MPa
- Static Axial Load = 200 N/mm in vertical direction (along 3 m dimension)

Solution

On the “Intro” worksheet area (Figure 1), select “One-Way and Two-Way Reinforced Masonry” and Metric units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Long Span, L = 5000 mm
- Short Span, H = 3000 mm
- Boundary Conditions = “Two-Way: Four Sides Supported-All Simple”
- Set the Response Type to “Flexural Only” and “Type I Cross Section”
- On the Structural & Material Properties input box fill in cells as follows:
  - Total Wall Thickness, t = 305 mm
  - Reinforcing Steel Spacing – Bars Spanning Parallel to L, b = 406 mm, Bars Spanning Parallel to H, bH = 406 mm
  - Reinforcing Steel Areas – Positive Moment Steel parallel to L, Asp = 122 mm^2, Positive Moment Steel parallel to H, Asp = 122 mm^2
  - Distance of Cover to Center of Bars, dc – Non-Loaded Side Spanning Parallel to = 152.5 (Same in the H direction). In both cases this is half the wall thickness.
  - Select “European Insulated Block” for Masonry Type

  - Masonry Compressive Strength, f'_m = 10.50 MPa
  - Masonry Dynamic Compr. Increase Factor = 1.19 (Typical Value, see SBEDS user manual)
  - Select Reinforcement = Grade 415
  - Enter 200,000 N/m as the Static Axial Load, P
  - Enter 3000 mm for the Span Length in Direction of Axial Load
- Select "Manual Input" under Blast Load Input Type, and "none (vertical component)" under Gravity Displacement
- Enter the appropriate values to define the triangular pressure history above in the Pressure-Time Input table
- Set the Response Criteria to "Combined Flexure & Compression" and "LLOP/Primary"
- Select "No Dynamic Axial Load"
- On the Solution Control input box, select a time step based on the recommended value.

After these steps, the input screen will look as shown on the following page.

One-Way and Two-Way Reinforced Masonry

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

Long Span Dimension, L:	5000	mm
Short Span Dimension, H:	3000	mm
Boundary Conditions:	Two-Way: Four Sides Supported - All Simple	
Response Type:	Flexural Only	Type I Cross Section

Structural & Material Properties

Total Wall Thickness, T:	305	mm
Resinforcing Steel Spacing **(See diagram in cell R37 for diagram of steel input terms)**		
Bars Spanning Parallel to L, b_L:	406	mm
Bars Spanning Parallel to H, bH:	406	mm
Reinforcing Steel Areas ***(Symmetric reinforcement assumed)**		
Positive Moment Steel Parallel to L, AspL:	122	mm^2
Positive Moment Steel Parallel to H, AspH:	122	mm^2
Negative Moment Steel Parallel to L, AsnL: *	122	mm^2
Negative Moment Steel Parallel to H, AsH: *	122	mm^2
Distance of Cover to Center of Bars: d ***(Symmetric reinforcement assumed)**		
Non-Loaded Side Spanning Parallel to L:	152.5	mm
Non-Loaded Side Spanning Parallel to H:	152.5	mm
Loaded Side Spanning Parallel to L: *	152.5	mm
Loaded Side Spanning Parallel to H:*	152.5	mm
Masonry Type:	European Insulated Block	
Leave Blank for non-CMU Masonr (Click for User Defined Masonry)	0	
Supported Weight, w:	0	kg/m^2
Masonry Compressive Strength on Gross Area, f'm:	10.50	MPa
Masonry Dynamic Compr. Increase Factor:	1.19	
Wall Self-Weight, W:	422.12	kg/m^2
Masonry Dynamic Compr. Strength, f'_{dm}:	12.50	MPa
Masonry Elastic Modulus, E_m:	10,500	MPa
Select Reinforcement:	A615, A616, A706 (All Gr. 415)	
Reinf. Steel Yield Strength, f_s:	415	MPa
Reinf. Steel Ultimate Strength, f_u: (Click for User Defined Steel)	620	MPa
Static Strength Increase Factor:	1.1	
Dynamic Increase Factor:	1.17	
Dynamic Reinf. Steel Yield Stress, f_{ds}:	534	MPa
Reinf. Steel Elastic Modulus, E_s:	200,000	MPa
Axial Load Input:	No Dynamic Axial Load	
Static Axial Load; P': (Note: P>=0)	200000	N/m
Span Length in Direction of Axial Load	3000	mm

See All COE Response Criteria

Blast Load Input Type

Manual input

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (kPa)
0	120
18	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (kg TNT)	R (m)

Blast Load Phase: Positive phase only

Charge Weight Load Type: Side-on

Parameters for Reflected Loads

Wall Height (m)[1]
Wall Width (m)[1]
Incidence Angle[2]

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Applied Blast Input File Not Selected

Response Criteria

Combined Flexure & Compression

LOP/Type: LLOP/Primary

θ (deg)	µ
2	N/A

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (long side) =	0.09	0.10
R (long side) =	0.26	0.24
F (short side) =	0.04	0.05
R (short side) =	0.11	0.10

Solution Control

Inbound Natural Period:	46.86	ms
Rebound Natural Period:	46.86	ms
Max Recommended Time Step:	0.13	msec
Time Step:	0.13	msec
% of Critical Damping:	0	%
Initial Velocity:	0	mm/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	422.12	422.12	kg/m^2
Load-Mass Factors, K_{LM}			
K_{LM1}	0.74	0.74	
K_{LM2}	0.74	0.74	
K_{LM3}	0.56	0.56	
K_{LM4}	0.56	0.56	
K_{LM5}	0.56	0.56	
Stiffness, K			
K1	5.59	5.59	kPa/mm
K2	5.59	5.59	kPa/mm
K3	0.00	0.00	kPa/mm
K4	0.00	0.00	kPa/mm
K5	0.00	0.00	kPa/mm
Resistance, R			
R1	38.34	-38.34	kPa
R2	38.34	-38.34	kPa
R3	38.34	-38.34	kPa
R4	38.34	-38.34	kPa

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the wall. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below.

For this problem, the calculated maximum dynamic displacement is 43.23 mm. This corresponds to a ductility ratio of 6.3 and a support rotation of 1.65 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the performance criteria for this type of component at this level of protection are only based on support rotation.

Under the Results Summary, SBEDS displays the calculated reactions and the shear capacity of the wall along both dimensions. For this example, the shear capacity is adequate as indicated by the "Shear is OK" message. Therefore, stirrups are not required. (See Example 9A for note regarding distribution of shear around openings.)

Results Summary

θ_{max} =	1.65 deg.	Design Criteria:	LLOP/Primary
μ =	6.30	Response OK compared to input design criteria	

X_{max} Inbound =	43.23 mm	at time =	30.94 msec
X_{min} Rebound =	0.00 mm	at time =	0.00 msec
R_{max} =	38.34 kPa	at time =	30.94 msec
R_{min} =	-29.84 kPa	at time =	54.60 msec
Shortest Yield Line Distance to Determine θ:			1500.0 mm

Equivalent Static Reactions*

Peak Reactions Based on Ultimate Flexural Resistance: Vu		
Vu at supports in L direction	41.6	N/mm
Vu at supports in H direction	41.7	N/mm
Maximum Vu at distance d from support *** =	38.1	N/mm
Shear Capacity		
Diagonal Shear Capacity: $V_{c,diag}$ =	44.9	N/mm
Tensile steel depth for shear calculations, d:	152.5	mm
Results based on Max Shear Region		
At support:	Shear is OK	
At distance d from support:	Shear is OK	
*Required Stirrups based on Max Shear Region, Av,req ** *		
Critical section @ support, A_{v,req_s}:	0.0000	mm^2/mm^2
Critical section at d, A_{v,req_d}:	0.0000	mm^2/mm^2

* Based only on larger of R_{max} or R_{min}, not including tension membrane or arching

**Multiply Av values by flexural bar spacing and stirrup spacing to get stirrup area

*** Vmax at distance d from support is conservatively overestimated

Example 10A: One-Way or Two-Way Unreinforced Masonry (English)

Analyze the response of a one-way 10 ft tall, 8 in thick lightweight CMU non-load bearing wall to the effects of 220 lbs of TNT at 150 ft of standoff with a 50 degree angle of incidence. The CMU wall is un-reinforced, ungrouted, and simply supported top and bottom. The wall is required to provide a LLOP for secondary type components in flexure. Include negative phase blast load and assume a response mode of brittle flexure and axial load arching. Use 2% of critical damping. The masonry compressive strength (f'_m) is 300 psi and the masonry dynamic tensile strength is 150 psi.

Analysis Parameters:

- One-way spanning lightweight CMU wall with simple supports
- L = 10 ft
- Thickness = 8 in
- Ungrouted
- LLOP for secondary components
- Brittle failure and axial load arching from self weight (not load bearing wall)
- Positive and negative phase blast loading from 220 lbs of TNT at 150 ft with an angle of incidence = 50 degrees
- 2% of critical damping (usually damping can be ignored, but it is more important to include for unreinforced masonry because of lower component strength and higher possible velocities during response)
- f'_m = 1300 psi, masonry dynamic tensile strength = 150 psi. Usually, the masonry tensile strength is controlled by the mortar to masonry adhesion and it has a dynamic strength of approximately 10% of the compression strength, in the range of 150 psi to 200 psi. See the SBEDS Methodology Manual distributed with SBEDS for more information.

Solution

On the “Intro” worksheet area (Figure 1), select “One-Way and Two-Way Unreinforced Masonry” and English units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Span, L = 10 ft
- Width Resisting Blast Load / Loaded Width; Bw = 1.0 (This is always the case for walls without blast-resistant openings, such as laminated windows.)
- Boundary and Load Conditions = “One-Way, Simple-Simple, Uniformly Loaded”
- Response Type = “Brittle Flexural Response with Axial Load”. Note that in this case the only axial load is from wall self weight above midheight – see the SBEDS Methodology Manual for more discussion in this response type.
- On the Structural & Material Properties input box fill the input cells as follows:
    - Select “None or Non-Structural” masonry type for the outer wall (this input is only used for masonry walls that are two wythes and are not composite)
    - Select “Lightweight CMU” masonry type for the inner wall and proceed to fill in the input cells
    - Total wall thickness, h = 7.625 in. (Actual dimension of a typical nominal 8 in CMU block)
    - Masonry Dynamic Tensile strength, f_{dt} = 150 psi
    - Masonry Compressive Strength f'_m = 1300 psi

- Masonry Dynamic Compr. Increase Factor = 1.19
- Percent of Void Space Grouted = 0 (wall is ungrouted)

- Choose “Charge weight and standoff” under Blast Load Input type
- Choose “None (vertical component)” under Gravity Displacement
- On the Charge weight and Standoff input box, enter the appropriate values for charge weight and standoff
- Select “Positive and Negative phase” under Blast Load Phase, and Reflected without clearing” under Charge Weight Load Type.
- Enter 50 as the Incidence Angle (Cell H35)
- Set the Response Criteria to “Flexure” and “LLOP/Secondary-NS”
- On the Solution Control input box, enter the time step for the analysis based on the recommended time step and enter 2% of critical damping

The input screen will appear as shown on the following page.

One-Way and Two-Way Unreinforced Masonry

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

Span Length, L:	10	ft
Width Resisting Blast Load / Loaded Width; Bw	1	Note:0<Bw<=1.0
Boundary and Load Conditions:	One-Way: Simple-Simple, Uniformly Loaded	
Response Type:	Brittle Flexural Response with Axial Load	

Structural & Material Properties

Wall Inputs	Outer Wall	Single or Inner Wall	
Masonry Type:	None or Non-Structural	Light Weight CMU	
Total Wall Thickness, h:	0	7.625	in
Supported Weight, w:		0	psf
Masonry Dynamic Tensile Strength, fdt:	0	150	psi
Masonry Compressive Strength, f'm:	0	1300	psi
Masonry Dynamic Compr. Increase Factor:	0	1.19	
Percent of Void Spaced Grouted	0	0	%
Masonry Dynamic Compr. Strength, f'_{dm}:	0	1,547	psi
Masonry Elastic Modulus, E_m:	0	1,300,000	psi
Poisson's Ratio ν:	0.2	0.2	
Wall Self-Weight, W:	0.00	29.30	psf
Moment of Inertia, I:	0.00	28.36	in^4/in
Section Modulus, S:	0.00	7.44	in^3/in
Cross Sectional Area, A:	0.00	3.70	in^2/in

Click for User Defined Masonry

Axial Load and Arching Parameters	Outer Wall	Single or Inner Wall	
Static Axial Load; P: (Note: P>=0)	0	0	lb/in
Leave Blank for No Rigid Boundary Arching		0	in

Calculated Properties

Flexural Moment Capacity, M:	0	1,116	lb-in/in

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (psi)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (lbs TNT)	R (ft)
220	150

Blast Load Phase: Positive and negative phase

Charge Weight Load Type: Reflected without Clearing

Parameters for Reflected Loads

Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	50

See notes under error messages

Load file name

Blast Load File Not Selected

Response Criteria

Flexure

LOP/Type: LLOP/Secondary-NS

θ (deg)	µ
4	N/A

See All COE Response Criteria

Dynamic Shear Factors

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

Solution Control

Inbound Natural Period:	34.42	ms
Rebound Natural Period:	34.42	ms
Max Recommended Time Step:	0.09	ms
Time Step:	0.09	ms
% of Critical Damping:	2	%
Initial Velocity:	0	in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	526.6	526.6	$psi\text{-}ms^2/in$
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	13.69	13.69	psi/in
K_2	13.69	0.00	psi/in
K_3	-13.69	13.69	psi/in
K_4	-0.01	-0.01	psi/in
K_5	0.00	0.00	psi/in
Resistance, R			
R_1	0.62	0.00	psi
R_2	0.62	0.00	psi
R_3	0.05	-0.05	psi
R_4	0.00	0.00	psi

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the Wall. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below.

For this problem, the calculated maximum dynamic displacement is 2.95 in. This corresponds to a ductility ratio of 65.14 and a support rotation of 2.81 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the performance criterion for this type of component at this level of protection is only based on support rotation.

Under the Results Summary, SBEDS displays the calculated reactions and the shear capacity of the wall along the supports. For this example, the shear capacity is adequate as indicated by the "Shear is OK" message. Therefore, stirrups are not required. (See Example 9A for note regarding shear distribution around openings.)

Results Summary

θ_{max} =	2.81	deg.	Design Criteria:	LLOP/Secondary-NS
μ =	65.14			Response OK compared to input design criteria

X_{max} Inbound =	2.95	in	at time =	68.49	msec
X_{min} Rebound =	0.00	in	at time =	0.00	msec
R_{max} =	0.62	psi	at time =	3.06	msec
R_{min} =	0.00	psi	at time =	0.00	msec

Shortest Yield Line Distance to Determine θ: 60.0 in

Equivalent Static Reactions*

Peak Reactions Based on Ultimate Flexural Resistance: Vu

Left Side Vu at support =	37	lb/in
Right Side Vu at support =	37	lb/in
Vu at distance d from support =	37	lb/in

*Shear Capacity ***	Outer Wall	Inner Wall	
Shear Area =	0.00	0.00	in^2/in
Diagonal Shear Capacity =		0	lb/in

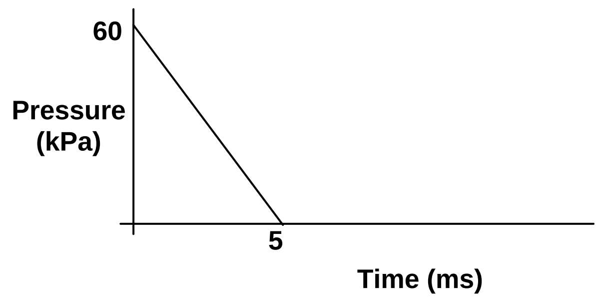
Results based on Max Shear Region

At support:	Shear is Not OK
At distance d from support:	Shear is Not OK

* Based on larger of inbound and rebound ultimate flexural resistance, not including arching or compression membrane.

Example 10B: One-Way or Two-Way Unreinforced Masonry (Metric)

Analyze the response of a one-way 3 m tall, 150 mm thick, European block wall to the effects of a blast load as defined below.



The wall is fully-grouted and simply supported top and bottom. The wall is required to provide LLOP for primary type components in flexure. The wall is built tightly inside a reinforced concrete frame along the top and bottom supports with mortar similar to that between the blocks (this requires very careful construction), so rigid arching can be included in the analysis. Use 2% of critical damping. The masonry compressive strength (f'_m) is 14 MPa, The masonry dynamic tensile strength is 1.4 MPa. The wall must provide a MLOP as a secondary type component.

Analysis Parameters:

- One-way European block wall
- L = 3 m
- Thickness = 150 mm
- Fully-grouted
- Simple-simple supports
- LLOP for primary components
- Include Rigid arching
- 2% Critical Damping
- f'_m = 14 MPa, Masonry dynamic tensile strength = 1.4MPa

Solution

On the “Intro” worksheet area (Figure 1), select “One-Way and Two-way Un-reinforced Masonry” and Metric units and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells (in yellow) as follows:

- Span, L = 3000 mm
- Width Resisting Blast Load / Loaded Width; Bw = 1.0
- Boundary and Load Conditions = “One-Way, Simple-Simple, Uniformly Loaded
- Response Type = “Rigid Arching Across Vertical Span”
- On the Structural & Material Properties input box fill the input cells as follows:
    - Select “None or Non-Structural” masonry type for the Outer wall, and enter 0 for all input cells under Outer Wall.
    - Select “European Insulated Block” masonry type for the Inner wall and proceed to fill in the input cells
    - Total wall thickness, h = 150 mm

  - Masonry Dynamic Tensile strength, fdt = 1.4 MPa
  - Masonry Compressive Strength f'm = 14 MPa
  - Masonry Dynamic Compr. Increase Factor = 1.19
  - Percent of Void Space Grouted = 100 (fully grouted)
- Choose "Manual Input" under Blast Load Input type
- Choose "None (vertical component)" under Gravity Displacement
- Enter the appropriate values in the Pressure-Time input table
- Set the Response Criteria to "Combined Flexure and Compression" and "MLOP/Secondary"
- On the Solution Control input box, select the time step for the analysis and enter 2% of critical damping

The input screen will appear as shown on the next page.

One-Way and Two-Way Unreinforced Masonry

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

Span Length, L:		3000	mm
Width Resisting Blast Load / Loaded Width; Bw		1	Note:0<Bw<=1.0
Boundary and Load Conditions:	One-Way: Simple-Simple, Uniformly Loaded		
Response Type:	Rigid Arching Across Vertical Span		

Structural & Material Properties

Wall Inputs	Outer Wall*	Single or Inner Wall	
Masonry Type:	None or Non-Structural	European Insulated Block	
Total Wall Thickness, h:	0	150	mm
Supported Weight, w:		0	kg/m²
Masonry Dynamic Tensile Strength, fdt:	0	1.4	MPa
Compressive Strength on Gross Area, f'm:	0	14	MPa
Masonry Dynamic Compr. Increase Factor:	0	1.19	
Percent of Void Spaced Grouted	0	0	%
Masonry Dynamic Compr. Strength, f'_{dm}:	0	17	MPa
Masonry Elastic Modulus, E_m:	0	14,000	MPa
Poisson's Ratio ν:	0.2	0.2	
Wall Self-Weight, W:	0.00	103.80	kg/m²
Moment of Inertia, I:	0.00	84375.00	mm⁴/mm
Section Modulus, S:	0.00	1125.00	mm³/mm
Cross Sectional Area, A:	0.00	75.00	mm²/mm

Click for User Defined Masonry

Axial Load and Arching Parameters	Outer Wall	Single or Inner Wall	
Static Axial Load; P: (Note: P>=0)	0	0	N/mm
Gap from Edge of Wall to Rigid Support, D:		0	mm

Calculated Properties

Moment Capacity, M:	0	1,575	N-mm/mm

* Compression membrane based only on single or inner wall

Blast Load Input Type

Manual input

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (kPa)
0	60
5	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (kg TNT)	R (m)

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected without Clearing

Parameters for Reflected Loads

Wall Height (m)[1]	
Wall Width (m)[1]	
Incidence Angle[2]	

See notes under error messages

Load file name

Applied Blast Input File Not Selected

Response Criteria

Combined Flexure & Compression

LOP/Type	LLOP/Primary
θ (deg)	µ
1.5	N/A

See All COE Response Criteria

Dynamic Shear Factors

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

Solution Control

Inbound Natural Period:	108.20	ms
Rebound Natural Period:	108.20	ms
Max Recommended Time Step:	0.30	ms
Time Step:	0.3	ms
% of Critical Damping:	2	%
Initial Velocity:	0	mm/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	103.8	103.8	kg/m²
Load-Mass Factors, K_{LM}			
K_{LM1}	0.66	0.66	
K_{LM2}	0.66	0.66	
K_{LM3}	0.66	0.66	
K_{LM4}	0.66	0.66	
K_{LM5}	0.66	0.66	
Stiffness, K			
K_1	0.23	0.23	kPa/mm
K_2	-0.39	0.00	kPa/mm
K_3	0.00	0.23	kPa/mm
K_4	0.00	-0.39	kPa/mm
K_5	0.00	0.00	kPa/mm
Resistance, R			
R_1	17.35	0.00	kPa
R_2	0.00	0.00	kPa
R_3	0.00	-17.35	kPa
R_4	0.00	0.00	kPa

After the input sheet is completed click the "Run SDOF" button at the top of the screen (See Figure 2) to calculate the dynamic response of the Wall. After the analysis is performed, a summary of the most important results will be displayed in the Results Summary box as illustrated below.

For this problem, the calculated maximum dynamic displacement is 37.53 mm. This corresponds to a ductility ratio of 0.5 and a support rotation of 1.43 degrees. Therefore, the response is under the allowable limits and the design is acceptable. Notice that the performance criterion for this type of component at this level of protection is only based on support rotation.

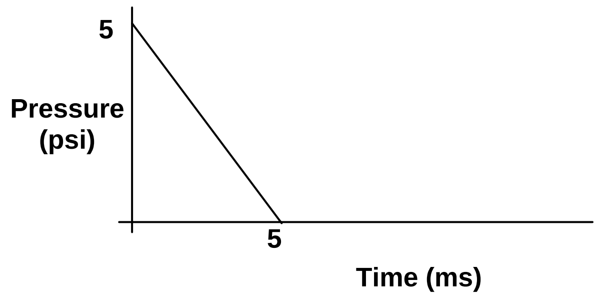
Under the Results Summary, SBEDS displays the calculated reactions and the shear capacity of the wall along the supports. For this example, the shear capacity is adequate as indicated by the "Shear is OK" message. Therefore, stirrups are not required. (See Example 9A for note regarding shear distribution around openings.)

Results Summary					
θ_{max} =	1.43	deg.	Design Criteria:	LLOP/Primary	
μ =	0.50		Response OK compared to input design criteria		
X_{max} Inbound =	37.39	mm	at time =	28.80	msec
X_{min} Rebound =	-35.96	mm	at time =	83.10	msec
R_{max} =	8.64	kPa	at time =	28.80	msec
R_{min} =	-8.31	kPa	at time =	83.10	msec
Shortest Yield Line Distance to Determine θ:				1500.0	mm

Equivalent Static Reactions*			
Peak Reactions Based on Ultimate Flexural Resistance: Vu			
Left Side Vu at support =		2	N/mm
Right Side Vu at support =		2	N/mm
Vu at distance d from support =		2	N/mm
*Shear Capacity ***	Outer Wall	Inner Wall	
Shear Area =	0.00	0.00	mm^2/mm
Diagonal Shear Capacity =		0.00	N/mm
Results based on Max Shear Region			
At support:		Shear is Not OK	
At distance d from support:		Shear is Not OK	
* Based on larger of inbound and rebound ultimate flexural resistance, not including arching or compression membrane.			

Example 11A: One-Way or Two-Way Wood Panel (English)

Analyze the flexural response of a ¾" thick plywood panel subject to an applied blast load as defined below.



The panel is 6 ft tall by 6 ft wide and is simply supported on all four sides. The panel must provide a LLOP for secondary type components in flexure. Use the following properties for the plywood panel: Density = 35 pcf, Dynamic Yield Strength = 2000 psi, Elastic Modulus = 1400000 psi, and Poisson's Ratio = 0.4. Note that the input dynamic yield strength for wood in SBEDS is based on five times the typical published modulus of rupture value, which is for long duration (i.e., 10 yr) static loading. This is discussed more in the SBEDS Methodology Manual.

Analysis Parameters:

- Two-way plywood panel
- Simply supported all four sides
- 0.75 in thick
- L = 6 ft, H = 6 ft
- LLOP for secondary type components required

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way or Two-Way Wood Panel" and English units, and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells in yellow with the appropriate values specified in the problem statement.

- Select "Manual Input" using the drop down menu under Blast Load Input Type and proceed to enter the pressure and time values from the triangular load illustrated above in the Pressure-time input table.
- Next, select "None (vertical component)" using the drop-down menu under Gravity Displacement.
- Set the response criteria to "Flexure" and "LLOP/Secondary-NS", and enter the time step for the analysis in the Solution Control input box based on the recommended time step.

The input screen should appear as shown on the next page.

One-Way and Two-Way Wood Panel

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

Long Span Dimension, L:	6	ft
Short Span Dimension, H:	6	ft
Boundary and Load Conditions:	Two-Way: Four Sides Supported - All Simple	

Structural & Material Properties

Panel Thickness, t:	0.75	in
Wood Density, γ:	35.0	lb/ft³
Dynamic Yield Strength in Flexure, f_y:	2000	psi
Elastic Modulus, E:	1400000	psi
Supported Weight, W:	0.0	lb/ft²
Poisson's Ratio, ν:	0.4	
Self-Weight, w:	2.19	lb/ft²
Moment of Inertia, I:	0.04	in⁴/in
Section Modulus, S:	0.09	in³/in

Calculated Properties

Moment Capacity:	187.5	lb-in/in

Blast Load Input Type

Manual input

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (psi)
0	5
5	0
20	0
30	0
40	0
50	0
60	0
70	0

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (long side) =	0.07	0.09
R (long side) =	0.18	0.16
F (short side) =	0.07	0.09
R (short side) =	0.18	0.16

Solution Control

Inbound Natural Period:	42.66	ms
Rebound Natural Period:	42.66	ms
Max Recommended Time Step:	0.12	ms
Time Step:	0.12	ms
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

Charge Weight and Stando

W (lbs TNT)	R (ft)

Blast Load Phase

Positive phase only

Charge Weight Load Type

Reflected without Clearing

Parameters for Reflected Load:

Wall Height (ft)¹

Wall Width (ft)¹

Incidence Angle²

See notes under error messages

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	39.3	39.3	psi-ms²/in
Load-Mass Factors, K_{LM}			
Elastic	0.63	0.63	
Elastic-Plastic	0.63	0.63	
Plastic	0.50	0.50	
Stiffness, K			
Elastic	0.54	0.54	psi/in
Elastic-Plastic	0.54	0.54	psi/in
Effective	0.54	0.54	psi/in
Resistance, R			
Elastic	0.77	-0.77	psi
Plastic	0.77	-0.77	psi
Equiv Yield Defl, X_E	1.43	1.43	in

Load file name

Applied Blast Input File Not Selected

Response Criteria

Flexure

LOP/Type	LLOP/Secondary-NS
θ (deg)	μ
N/A	3

See All COE Response Criteria

After all the input cells are completed, click on the “RUN SDOF” button at the top of the screen (See Figure 2) to initiate the analysis. After the analysis is completed, SBEDS will display a summary of the results in the Results Summary as illustrated below.

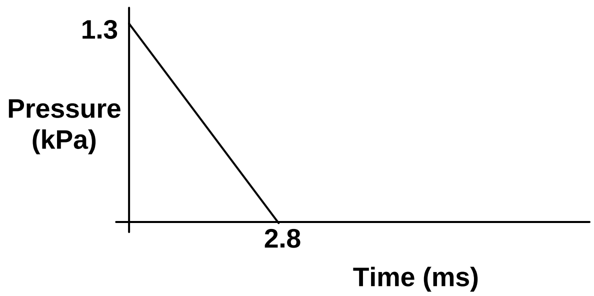
Results Summary			
θ_{max} =	6.39 deg.	Design Criteria:	LLOP/Secondary-NS
μ =	2.82	Response OK compared to input design criteria	
X_{max} Inbound =	4.03 in	at time =	16.20 msec
X_{min} Rebound =	0.00 in	at time =	0.00 msec
R_{max} =	0.77 psi	at time =	16.20 msec
R_{min} =	-0.77 psi	at time =	37.56 msec
Shortest Yield Line Distance to Determine θ:			36.0 in
Equivalent Static Reactions*			
Peak Reactions Based on Ultimate Flexural Resistance: Vu			
Vu at supports in L direction			16 lb/in
Vu at supports in H direction			17 lb/in

* Based on larger of inbound and rebound ultimate flexural resistance.

As seen above, the maximum calculated deflection for this panel was 4.03 in. This corresponds to a ductility ratio of 2.83 which is less than the allowable value of 3 in the Response Criteria. Therefore, the panel is acceptable as indicated by the “Response OK compared to input design criteria” message in SBEDS. The bottom part of the Results Summary displays the calculated reactions, which are used to design the connections and check for shear failure.

Example 11B: One-Way or Two-Way Wood Panel (Metric)

Analyze the flexural response of a 12.5 mm thick plywood panel subject to a blast load as defined below.



The panel is 1.5 m long and is only supported at the top and bottom (simple supports). The panel must provide a HLOP for secondary type components in flexure. Use the following properties for the plywood panel: Density = 575 kg/m^3, Dynamic Yield Strength = 1.4 MPa, Elastic Modulus = 9650 MPa, and Poisson's Ratio = 0.4

Analysis Parameters:
- One-way plywood panel
- 12.5mm thick
- L = 1.5 m
- Simple-simple supports
- HLOP for secondary type components required

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way or Two-Way Wood Panel" and Metric units, and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells in yellow with the appropriate values specified in the problem statement.

- Select "Manual Input" using the drop down menu under Blast Load Input Type and proceed to enter the pressure and time values from the triangular load illustrated above in the Pressure-time input table.
- Next, select "None (vertical component)" using the drop-down menu under Gravity Displacement.
- Finally, set the response criteria to "Flexure" and "HLOP/Secondary-NS", and enter the time step for the analysis in the Solution Control input box based on the recommended time step.

The input screen should appear as shown on the next page.

One-Way and Two-Way Wood Panel

User Info: Fill in Yellow Cells, See Note Below for White Cells		
Length, L:	1500	mm
Leave Input Blank for One-Way Response	0	mm
Boundary and Load Conditions:	One-Way: Simple-Simple, Uniformly Loaded	
Structural & Material Properties		
Panel Thickness, t:	13	mm
Wood Density, γ:	575.0	kg/m^3
Dynamic Yield Strength in Flexure, f_y:	1.40	MPa
Elastic Modulus, E:	9650.00	MPa
Supported Weight, W:	0.0	kg/m^2
Poisson's Ratio, ν:	0.4	
Self-Weight, w:	7.19	kg/m^2
Moment of Inertia, I:	162.76	mm^4/mm
Section Modulus, S:	26.04	mm^3/mm
Calculated Properties		
Moment Capacity:	36.5	N-mm/mm

Blast Load Input Type
Manual input
Gravity Displacement
None (vertical component)

Pressure-Time Input	
Time	Pressure
(ms)	(kPa)
0	1.3
2.8	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff	
W	R
(kg TNT)	(m)
Blast Load Phase	
Positive phase only	
Charge Weight Load Type	
Reflected without Clearing	
Parameters for Reflected Loads	
Wall Height (m)[1]	
Wall Width (m)[1]	
Incidence Angle[2]	

See notes under error messages

Load file name	
Blast Load File Not Selected	
Response Criteria	
Flexure	
LOP/Type	HLOP/Secondary-NS
θ(deg)	μ
N/A	1

See All COE Response Criteria

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

Solution Control		
Inbound Natural Period:	96.38	ms
Rebound Natural Period:	96.38	ms
Max Recommended Time Step:	0.27	ms
Time Step:	0.25	ms
% of Critical Damping:	0	%
Initial Velocity:	0	mm/ms

SDOF Properties			
Property	Inbound	Rebound	Units
Mass, M	7.2	7.2	kg/m^2
Load-Mass Factors, K_{LM}			
Elastic	0.78	0.78	
Elastic-Plastic	0.78	0.78	
Plastic	0.66	0.66	
Stiffness, K			
Elastic	0.02	0.02	kPa/mm
Elastic-Plastic	0.02	0.02	kPa/mm
Effective	0.02	0.02	kPa/mm
Resistance, R			
Elastic	0.13	-0.13	kPa
Plastic	0.13	-0.13	kPa
Equiv Yield Defl., X_E	5.44	5.44	mm

After all the input cells are completed, click on the "RUN SDOF" button at the top of the screen (See Figure 2) to initiate the analysis. After the analysis is completed, SBEDS will display a summary of the results in the Results Summary as illustrated below.

Results Summary					
θ_{max} =	0.38 deg.	Design Criteria:	HLOP/Secondary-NS		
μ =	0.91	Response OK compared to input design criteria			
X_{max} Inbound =	4.98	mm	at time =	25.00	msec
X_{min} Rebound =	-4.97	mm	at time =	73.25	msec
R_{max} =	0.12	kPa	at time =	25.00	msec
R_{min} =	-0.12	kPa	at time =	73.25	msec
Shortest Yield Line Distance to Determine θ:				750.0	mm
Equivalent Static Reactions*					
Peak Reactions Based on Ultimate Flexural Resistance: Vu					
Vu at right support =				0.10	N/mm
Vu at left support =				0.10	N/mm

* Based on larger of inbound and rebound ultimate flexural resistance.

As seen above, the maximum calculated deflection for this panel was 4.98 mm. This corresponds to a ductility ratio of 0.91 which is less than the allowable value of 1.0 in the Response Criteria. Therefore, the panel is acceptable as indicated by the "Response OK compared to input design criteria" message in SBEDS. The bottom part of the Results Summary displays the calculated reactions, which are used to design the connections and to check for shear failure.

Example 12A: One-Way Wood Beam or Beam Column (English)

Analyze the response of 2x4 wall stud to the effects of a blast load generated by 1000 lbs of TNT at 850 ft of distance with an incidence angle of 30 degrees. The studs are 10 ft tall and are spaced at 16 in on center. All studs are Spruce-Pine-Fir. Conservatively assume "Stud" grade of wood (No. 2 grade can often be assumed for commercial or government construction). Assume a supported weight from cladding of 3 psf. Include clearing effects in your analysis based on a wall surface of 33 ft x 33 ft. The walls of this building are non-load bearing and must provide a LLOP for secondary type components in flexure.

Analysis Parameters:

- 2x4 Stud Grade Spruce-Pine-Fir
- L = 10 ft
- Stud Spacing B = 1.33 ft
- Supported weight = 3 psf
- Clearing effects for a 33 ft x 33 ft wall
- LLOP for secondary type components required
- 1000 lbs of TNT at 850 ft, with incidence angle = 30 degrees.

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way Wood Beam or Beam Column" and English units, and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells in yellow with the appropriate values specified in the problem statement. For this particular problem, the input sheet is completed as follows:

- Span, L = 10 ft
- Spacing, B = 1.33 ft
- Boundary Conditions: "Simple-Simple, Uniformly Loaded"
- On the Structural & Material Properties section of the input sheet, complete as follows:
    - Section Height, H = 3.5 in (actual depth dimension for a 2x4)
    - Section Width, W = 1.5 in (actual width dimension for a 2x4)
    - Wood Density = 35 pcf (Typical value for wood)
    - Select Wood Species: "SPRUCE-PINE-FIR", Select Grade: "Stud"
    - Supported Weight, W = 3 psf
- Blast Load Input Type: "Charge Weight and standoff"
- Gravity Displacement: "None (vertical component)
- On the Charge Weight and Standoff input table, enter the appropriate values of charge weight, and standoff. Use the drop-down menu under Blast Load Phase to select "Positive phase only."
- Under Charge Weight Load Type, select "Reflected with Clearing" and enter the appropriate values of 33 ft x 33 ft as the wall height and width and an angle of incidence of 30 degrees under "Parameters for Reflected Loads".
- Set the Response Criteria to "Flexure" and "LLOP/Secondary-NS"
- Select " No Dynamic Axial Load"
- Enter a time step for the analysis based on the recommended value

After the input cells are filled in, the input sheet should look as shown on the next page.

Wood Beam or Beam-Column

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

Span, L:	10	ft
Spacing, B:	1.33	ft
Boundary and Load Conditions:	Simple-Simple, Uniformly Loaded	

Structural & Material Properties

Section Height, H:	3.50	in
Section Width, W:	1.50	in
Wood Density, γ:	35	lb/ft^3
Wood Species: SPRUCE-PINE-FIR	Grade: Stud	
Dynamic Yield Strength in Flexure, f_y:	3375	psi
Elastic Modulus, E:	1200000	psi
Loaded Area Factor - Enter 1.0 for Uniform Load	1	
Supported Weight, W:	3.00	psf
No Dynamic Axial Load — [4]Static Axial Load, P:	0	lb
Leave blank for No Dynamic Axial Load		ft
Moment of Inertia, I:	5.36	in^4
Section Modulus, S:	3.06	in^3

Click for User Defined Wood

Calculated Properties

Moment Capacity, M_p:	10,336	lb-in
Equivalent P-delta load factor	0.00	1/in^2

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (psi)
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W (lbs TNT)	R (ft)
1000	850

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected with Clearing

Parameters for Reflected Loads

Wall Height (ft)[1]	33
Wall Width (ft)[1]	33
Incidence Angle[2]	30

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Applied Blast Input File Not Selected

Response Criteria

Flexure

LOP/Type: LLOP/Secondary-NS

θ (deg)	μ
N/A	3

See All COE Response Criteria

Dynamic Shear Factors

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

Solution Control

Inbound Natural Period:	121.17	ms
Rebound Natural Period:	121.17	ms
Max Recommended Time Step:	0.33	ms
Time Step:	0.33	ms
% of Critical Damping:	0	%
Initial Velocity:	0	in/ms

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	71.2	71.2	psi-ms^2/in
Load-Mass Factors, K_{LM}			
Elastic	0.78	0.78	
Elastic-Plastic	0.78	0.78	
Plastic	0.66	0.66	
Stiffness, K			
Elastic	0.15	0.15	psi/in
Elastic-Plastic	0.15	0.15	psi/in
Effective	0.15	0.15	psi/in
Resistance, R			
Elastic	0.36	-0.36	psi
Plastic	0.36	-0.36	psi
Equiv Yield Defl., X_E	2.41	-2.41	in

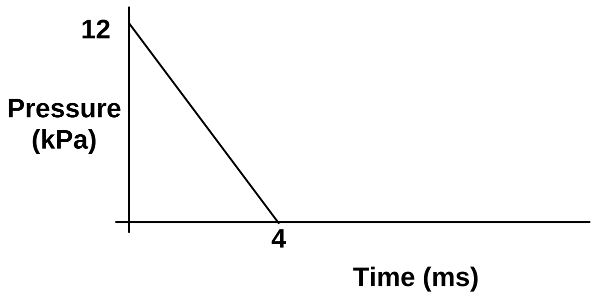
After all the input cells are completed, click on the "RUN SDOF" button at the top of the screen (See Figure 2) to initiate the analysis. After the analysis is completed, SBEDS will display a summary of the results in the Results Summary as illustrated below.

Results Summary						
θ_{max} =	6.35 deg.	Design Criteria:	LLOP/Secondary-NS			
μ =	2.77	Response OK compared to input design criteria				
X_{max} Inbound =	6.67	in	at time =	57.75	msec	
X_{min} Rebound =	0.00	in	at time =	0.00	msec	
R_{max} =	0.36	psi	at time =	57.75	msec	
R_{min} =	-0.36	psi	at time =	118.47	msec	
Shortest Yield Line Distance to Determine θ:				60.0	in	
Equivalent Static Reactions*						
Peak Reactions Based on Ultimate Flexural Resistance: Vu						
V_uL =				345	lb	
V_uR =				345	lb	
* Based on larger of inbound and rebound ultimate flexural resistance.						

As seen above, the maximum calculated deflection for this stud was 6.67 in. This corresponds to a ductility ratio of 2.77 which is less than the allowable value of 3 in the Response Criteria. Therefore, the stud is acceptable as indicated by the "Response OK compared to input design criteria" message in SBEDS. Notice that the Response Criteria for this type of components at this Level of Protection is dependant only on ductility ratio. The bottom part of the Results Summary displays the calculated reactions, which are used to design the connections and supports and to check for shear failure.

Example 12B: One-Way Wood Beam or Beam-Column (Metric)

Analyze the flexural response of a 150 mm x 150 mm No. 1 Grade Hem-Fir column with an axial load of 160 kN subject to the applied blast load below transferred into the column by a girt connected at mid-height. The static axial load is calculated as recommended in PDC TR-08-06 Revision 1 including the effects of the dynamic reaction load from supported roof members.



The columns in this building are 3 m in height and are spaced at 3 m on center. The columns are required to provide a MLOP for primary type components under combined flexure and compression.

Analysis Parameters:

- 150 mm x 150 mm No. 1 Hem-Fir column
- Axial load, P = 160 kN
- L = 3 m
- Spacing of columns, B = 3 m
- MLOP for primary type components under combined flexure and compression
- Concentrated blast load at mid-span from supported girt

Solution

On the "Intro" worksheet area (Figure 1), select "One-Way Wood Beam or Beam Column" and Metric units, and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells in yellow with the appropriate values specified in the problem statement. For this particular problem, the input sheet is completed as follows:

- Span, L = 3000 mm
- Spacing, B = 3000 mm
- Boundary and Load Conditions: "Simple-Simple, Conc. Load at Mid-span"
- On the Structural & Material Properties section of the input sheet, complete as follows:
    - Section Height, H = 150 mm
    - Section Width, W = 150 mm
    - Wood Density = 580 kg/m^3 (typical value for wood)
    - Wood Species: "HEM-FIR", Grade "No. 1"
    - Set Loaded Area Factor = 0.5 to account for fact that only the middle half of the wall transfers load into the girt that loads the column . The top and bottom quarter spans of the wall transfer blast load directly into the floor and roof diaphragms.
    - Supported Weight, W = 15 kg/m^2
    - Static Axial Load, P = 160000 N

- Blast Load Input Type: “Manual Input”
- Gravity Displacement: “None (vertical component)”
- Enter the appropriate values on the Pressure-Time input table from the triangular load history given above.
- Set the Response Criteria to “Combined Flexure & Compression” and “MLOP/Primary”
- Select “ No Dynamic Axial Load”
- Enter a time step for the analysis equal or less than the recommended value

After the input cells are filled in, the input sheet should look as shown on the next page.

Wood Beam or Beam-Column

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

Span, L:	3000	mm
Spacing, B:	3000	mm
Boundary and Load Conditions:	Simple-Simple, Conc. Load atMidspan	

Structural & Material Properties

Section Height, H:	150	mm
Section Width, W:	150	mm
Wood Density, γ:	580	kg/m³
Wood Species: HEM-FIR	Grade: No. 1	
Dynamic Yield Strength in Flexure, f_y:	33.6	MPa
Elastic Modulus, E:	10342	MPa
Loaded Area Factor Applied to L*B, Af:(Af<=1)	0.5	
Supported Weight, W:	15	kg/m²
No Dynamic Axial Load — *Static Axial Load, P:	160000	N
Leave blank for No Dynamic Axial Load		mm
Moment of Inertia, I:	42187500	mm⁴
Section Modulus, S:	562500	mm³

Click for User Defined Wood

Calculated Properties

Moment Capacity, M_r:	14,906,716	N-mm
Equivalent P-delta load factor	0.00	1/mm²

Blast Load Input Type

Manual input

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time (ms)	Pressure (kPa)
0	12
4	0
35	0
38	0
40	0
50	0
60	0
70	0

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F constant =	-0.28	-0.25
R constant =	0.78	0.75

Solution Control

Inbound Natural Period:	46.60	ms
Rebound Natural Period:	46.60	ms
Max Recommended Time Step:	0.13	ms
Time Step:	0.1	ms
% of Critical Damping:	0	%
Initial Velocity:	0	mm/ms

Charge Weight and Standoff

W (kg TNT)	R (m)

Blast Load Phase: Positive phase only

Charge Weight Load Type: Reflected with Clearing

Parameters for Reflected Loads

- Wall Height (m)[1]
- Wall Width (m)[1]
- Incidence Angle[2]

See notes under error messages

Load Files-AXIAL(above),BLAST(below)

- AxialLoad Input File Not Selected
- Applied Blast Input File Not Selected

Response Criteria

Combined Flexure & Compression

LOP/Type: MLOP/Primary

θ (deg)	μ
N/A	1

See All COE Response Criteria

SDOF Properties

Property	Inbound	Rebound	Units
Mass, M	19.4	19.4	kg/m²
Load-Mass Factors, K_{LM}			
Elastic	0.49	0.49	
Elastic-Plastic	0.49	0.49	
Plastic	0.33	0.33	
Stiffness, K			
Elastic	0.17	0.17	kPa/mm
Elastic-Plastic	0.17	0.17	kPa/mm
Effective	0.17	0.17	kPa/mm
Resistance, R			
Elastic	4.42	-4.42	kPa
Plastic	4.42	-4.42	kPa
Equiv Yield Defl., X_E	25.62	-25.62	mm

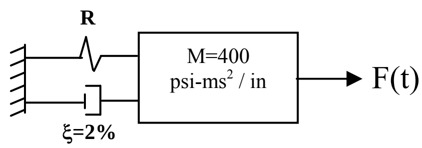
After all the input cells are completed, click on the “RUN SDOF” button at the top of the screen (See Figure 2) to initiate the analysis. After the analysis is completed, SBEDS will display a summary of the results in the Results Summary as illustrated below.

Results Summary			
θ_{max} =	0.84 deg.	Design Criteria:	MLOP/Primary
μ =	0.85	Response OK compared to input design criteria	
X_{max} Inbound =	21.90 mm	at time =	15.00 msec
X_{min} Rebound =	-21.86 mm	at time =	42.40 msec
R_{max} =	3.77 kPa	at time =	15.00 msec
R_{min} =	-3.77 kPa	at time =	42.40 msec
Shortest Yield Line Distance to Determine θ:			1500.0 mm
Equivalent Static Reactions*			
Peak Reactions Based on Ultimate Flexural Resistance: Vu			
V_uL =			9,938 N
V_uR =			9,938 N
* Based on larger of inbound and rebound ultimate flexural resistance.			

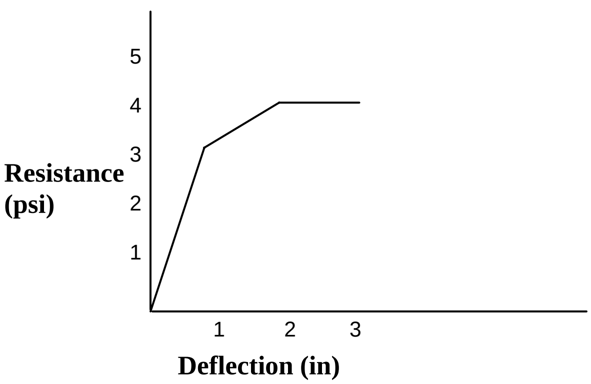
As seen above, the maximum calculated deflection for this column is 21.90 mm. This corresponds to a ductility ratio of 0.85 which is less than the allowable value of 1.0 in the Response Criteria. Therefore, the column is acceptable as indicated by the “Response OK compared to input design criteria” message in SBEDS. Notice that the Response Criteria for this type of components at this Level of Protection is dependant only on ductility ratio. The bottom part of the Results Summary displays the calculated reactions, which are used to design the connections.

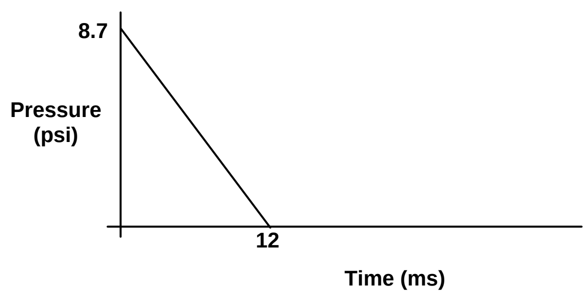
Example 13A: General SDOF (English)

The following spring-mass system is subjected to a force F(t). Use SBEDS to calculate the maximum spring deflection. Assume K_{lm} values are the same as those for a fixed-end beam. The spring has damping equal to 2% of critical damping. The spring-mass system represents a simply supported beam, and therefore has the dynamic reaction factors shown below based on information in TM 5-1300 and the SBEDS Methodology Manual.



Dynamic Shear Factors		
Shear Constant	**Elastic**	**Plastic**
F (long side) =	0.39	0.38
R (long side) =	0.11	0.12





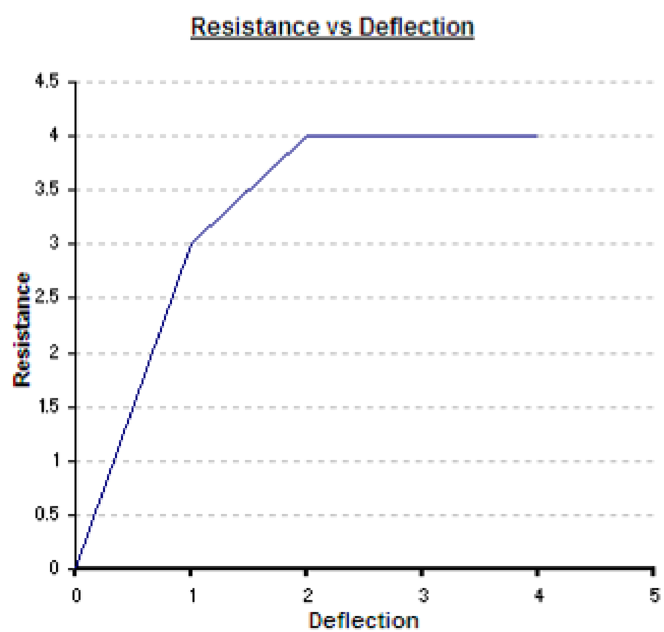
Solution

On the “Intro” worksheet area (Figure 1), select “General SDOF Analysis” and English units, and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells in yellow with the appropriate values specified in the problem statement. For this particular problem, the input sheet is completed as follows:

- Blast Load Input Type: “Manual Input”
- Gravity Displacement: “None (vertical component)”
- Enter appropriate values from triangular load above into Pressure-Time input table
- Leave blank the input cells for Response Criteria.
- Enter the Dynamic Shear Factors shown above.
- Select “No Dynamic Axial Load”
- On the Solution Control input box, select a time step for your analysis based on the recommended time step, and enter 2% critical damping.
- On the SDOF Properties input table, enter the given value for the Mass of the system and fill in the table as shown next. The values of stiffness “K” correspond to the slope of the resistance vs. deflection curve given above. The input Equivalent Elastic Displacement is conservatively taken as the first yield deflection in this case, which corresponds to 1 in. The equivalent elastic yield deflection can also be input if significant yielding is expected at all maximum moment regions. This input value is used to calculate the ductility ratio.

- The rebound flag is set to 1.0 (default value), indicating the typical case of no special rules regarding rebound stiffnesses. (The special rules are only applicable for components with compression membrane or brittle flexural cracking, which are both indicated by negative input stiffness values.)
- Input response criteria (a support rotation of 3 degrees and a ductility ratio of 2 are used in this example.)

After the input screen is completed, check the resistance vs. deflection curve in SBEDS to make sure it matches the resistance vs. deflection curve provided in the problem statement. The resistance vs. deflection curve in SBEDS (located to the right of the input screen area) will look as follows.



Blast Load Input Type

Manual input

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time	Pressure
(ms)	psi
0	8.7
12	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W	R
(lbs TNT)	(ft)

Blast Load Phase

Positive phase only

Charge Weight Load Type

Side-on

Parameters for Reflected Loads

Wall Height (ft)[1]

Wall Width (ft)[1]

Incidence Angle[2]

See notes under Input Design Criteria

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Blast Load File Not Selected

Response Criteria

η(deg)	η
3	2

See All COE Response Criteria

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (long side) =	0.39	0.38
R (long side) =	0.11	0.12
F (short side) =	0	0
R (short side) =	0	0

Note: Dynamic shear factor input is optional

Solution Control

Inbound Natural Period:	64.08	ms
Rebound Natural Period:	64.08	ms
Max Recommended Time Step:	0.18	ms
Time Step:	0.18	ms
% of Critical Damping:	2	%
Initial Velocity:	0	in/ms
Initial Displacement:	0	in

SDOF Properties*

Property		Inbound	Rebound **	Units
Mass, M		400.0	400.0	psi-ms2/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			Rebound flag*	1
	K_1	3.00	3.00	psi/in
	K_2	1.00	1.00	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	3.00	-3.00	psi
	R_2	4.00	-4.00	psi
	R_3	4.00	-4.00	psi
	R_4	4.00	-4.00	psi
Yield Displacement, x		No Input Required for xi Values Below		
Note:	x1	0.00	0.00	in
	x2	0.00	0.00	in
	x3	0.00	0.00	in
	x4	0.00	0.00	in
Equiv Elastic Displacement, X_E		1.00	-1.00	in
Shortest Yield Line Distance to Determine η:			60.0	in
Equivalent P-delta Axial Load Factor; W_F: (Enter W_F >=0)			0	1/in^2
No Dynamic Axial Load		[4] Static Axial Load:[5]	0	lb/in
Strain at First Yield for Strain-Rate			0	in/in

*Typically Rebound Flag = 1.See Help document for compression membrane,brittle cracking.

** User can overwrite yellow above cells in Rebound column

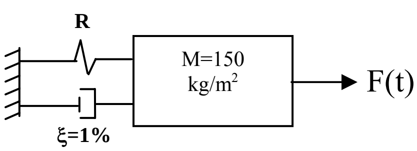
After all the input cells are completed, click on the "RUN SDOF" button at the top of the screen (See Figure 2) to initiate the analysis. A message will pop up announcing that "No Yield Distance was input", click OK to continue. Yield distance is used when the SDOF is representative of a structural component with known dimensions and the Response Criteria requires the calculation of the support rotations. This example represents a general SDOF system, and only the maximum spring displacement is of interest. The maximum calculated displacement was 1.71 in. As illustrated below in the Results Summary box.

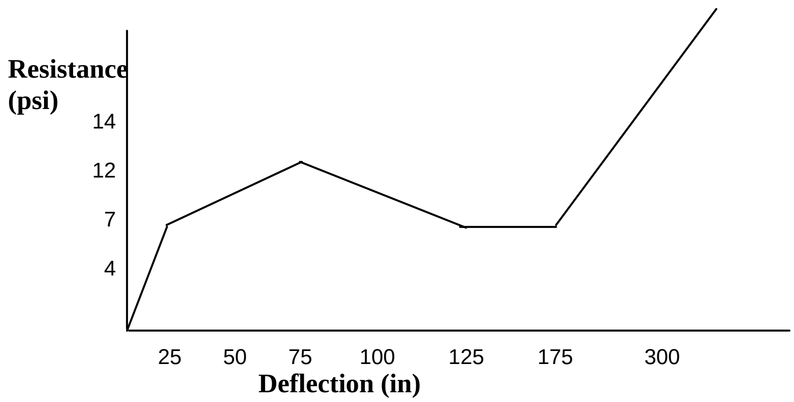
Results Summary					
θ_{max} =	1.63	deg.	Response OK compared to input design criteria		
μ =	1.71				
X_{max} Inbound =	1.71	in	at time =	21.78	msec
X_{min} Rebound =	-0.70	in	at time =	54.36	msec
R_{max} =	3.70	psi	at time =	21.78	msec
R_{min} =	-3.17	psi	at time =	54.36	msec

.

Example 13B: General SDOF (Metric)

The following spring-mass system represents a one-way structural slab with a span of 3048 mm. Analyze the response of the system to the positive and negative phase fully reflected blast load from 300 kg of TNT at 25 m. Specific requirements for this component require that the support rotation be limited to 12 degrees and the ductility ratio to 20. The component has a resistance-deflection relationship as shown below, which represents a component with flexure, compression membrane, and tension membrane response. The load-mass factors will be input for these response modes, where 0.78 is used for initial flexural mode followed by 0.66 for compression and tension membrane response modes and plastic flexural response. 1% of critical damping will be assumed for this example (this can also be neglected).





Resistance vs. deflection

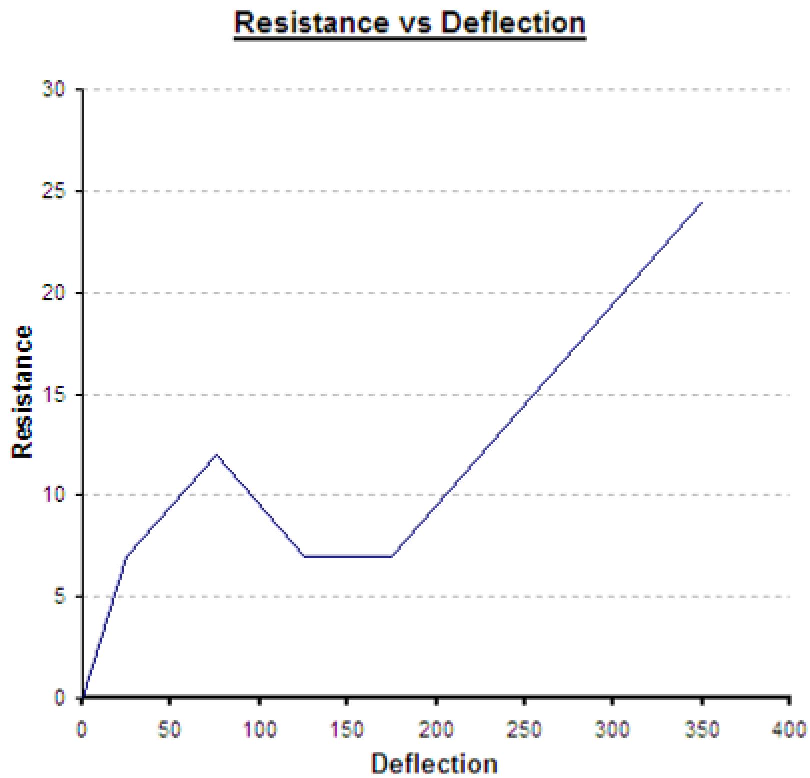
Solution

On the “Intro” worksheet area (Figure 1), select “General SDOF Analysis” and Metric units, and click the button near the bottom of the page to initiate the component input sheet. On the input sheet, fill in the input cells in yellow with the appropriate values specified in the problem statement. For this particular problem, the input sheet is completed as follows:

- Blast Load Input Type: “Charge weight and standoff”
- Gravity Displacement: “None (vertical component)”
- Enter the appropriate values for charge weight and standoff. Make sure to include positive and negative phase, and reflected without clearing.
- Enter 0 for the incidence angle (fully reflected load)
- Enter 12 for the rotation and 20 for ductility under Response Criteria
- Enter 0 for all cells under Dynamic Shear Factors. Dynamic reaction loads are not of interest in this case. The static equivalent shear loads will be compared against the component shear capacity outside of SBEDS.
- Select “No Dynamic Axial Load”
- On the Solution Control input box, select a time step for your analysis, and enter 1% critical damping.
- On the SDOF Properties input table, enter the given value for the Mass of the system and fill in the table as shown next. The values of stiffness “K” correspond to the slope of the resistance vs. deflection curve given above. The Equivalent Elastic Displacement is taken as the point at which flexural yielding occurs, which corresponds to 25 mm in the resistance vs. deflection curve given in the problem statement. Enter 1524 mm for

Shortest Yield Line Distance to Determine Θ, which corresponds to half the span of the slab. Yield line theory from TM 5-1300 can be used to determine the shortest yield line distance from the point of maximum deflection to a support for a two-way slab.

After the input screen is completed, check the resistance vs. deflection curve in SBEDS to make sure it matches the resistance vs. deflection curve provided in the problem statement. The resistance vs. deflection curve located to the right of the input screen area in SBEDS will look as follows.



After the input is completed, the input sheet should look as shown on the next page.

Blast Load Input Type

Charge weight and standoff

Gravity Displacement

None (vertical component)

Pressure-Time Input

Time	Pressure
(ms)	kPa
0	0
10	0
20	0
30	0
40	0
50	0
60	0
70	0

Charge Weight and Standoff

W	R
(kg TNT)	(m)
300	25

Blast Load Phase

Positive and negative phase

Charge Weight Load Type

Reflected without Clearing

Parameters for Reflected Loads

Wall Height (ft)[1]	
Wall Width (ft)[1]	
Incidence Angle[2]	0

See notes under Input Design Criteria

Load Files-AXIAL(above),BLAST(below)

AxialLoad Input File Not Selected

Blast Load File Not Selected

Response Criteria

◊ (deg)	◊
12	20

See All COE Response Criteria

Dynamic Shear Factors

Shear Constant	Elastic	Plastic
F (long side) =	0	0
R (long side) =	0	0
F (short side) =	0	0
R (short side) =	0	0

Note: Dynamic shear factor input is optional

Solution Control

Inbound Natural Period:	128.44	ms
Rebound Natural Period:	39.24	ms
Max Recommended Time Step:	0.35	ms
Time Step:	0.04	ms
% of Critical Damping:	1	%
Initial Velocity:	0	mm/ms
Initial Displacement:	0	mm

SDOF Properties*

Property		Inbound	Rebound **	Units
Mass, M		150.0	150.0	kg/m2
Load-Mass Factors, K_{LM}				
	K_{LM1}	0.78	0.78	
	K_{LM2}	0.66	0.66	
	K_{LM3}	0.66	0.66	
	K_{LM4}	0.66	0.66	
	K_{LM5}	0.66	0.66	
Stiffness, K			Rebound flag*	0
	K_1	0.28	3.00	kPa/mm
	K_2	0.10	2.00	kPa/mm
	K_3	-0.10	-2.00	kPa/mm
	K_4	0.00	0.00	kPa/mm
	K_5	0.10	0.50	kPa/mm
Resistance, R				
	R_1	7.00	-7.00	kPa
	R_2	12.00	-12.00	kPa
	R_3	7.00	-7.00	kPa
	R_4	7.00	-7.00	kPa
Yield Displacement, x		No Input Required for xi Values Below		
Note:	x1	0.00	0.00	mm
	x2	0.00	0.00	mm
	x3	0.00	0.00	mm
	x4	175.00	-175.00	mm
Equiv Elastic Displacement, X_E		25.00	-1.00	mm

Shortest Yield Line Distance to Determine ◊:	1524.0	mm
Equivalent P-delta Axial Load Factor; W_F: (Enter W_F >=0)	0	1/mm^2
No Dynamic Axial Load — [4] Static Axial Load:[5]	0	N/m
Strain at First Yield for Strain-Rate	0	mm/mm

*Typically Rebound Flag = 1.See Help document for compression membrane,brittle cracking.

** User can overwrite yellow above cells in Rebound column

After all the input cells are completed, click on the “RUN SDOF” button at the top of the screen (See Figure 2) to initiate the analysis. The results of the analysis are summarized in the Results Summary box illustrated below. For this problem, the maximum calculated displacement is 318.8 mm. This corresponds to a rotation of 11.8 degrees, and a ductility ratio of 12.74. Both values are under the specified limits for this analysis which is indicated by the “Response OK compared to input design criteria” message in SBEDS.

Results Summary						
θ_{max} =	11.81	deg.	Response OK compared to input design criteria			
μ =	12.74					
X_{max} Inbound =	318.60	mm	at time =	51.60	msec	
X_{min} Rebound =	0.00	mm	at time =	0.00	msec	
R_{max} =	21.32	kPa	at time =	51.60	msec	
R_{min} =	-12.00	kPa	at time =	60.64	msec	