TECHNICAL REPORT

TR-NAVFAC EXWC-SH-2403

NAVFAC EXWC Single-Degree of Freedom Dynamic Analysis Spreadsheet Version 2

User Manual

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December 2023

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EXECUTIVE SUMMARY

This report serves as the user manual for the NAVFAC EXWC Single-Degree-of-Freedom Dynamic Analysis Spreadsheet (NESDAS) Version 2, a software tool developed by the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC). The software tool is a module developed within Microsoft Excel, intended for the analysis of the dynamic response of single-degree-of-freedom systems (SDOF) subjected to blast loads, in support of protective construction analysis done for evaluation of structures for explosive safety in accordance with criteria established by the Department of Defense (DoD).

This report details the user interface of the NESDAS software, and provides guidance to the user in the use of the software, as well as limitations in its current functions. The report also provides a description of the analytical methods and assumptions that are utilized within the software tool. Finally, the report provides an initial validation study, comparing results obtained by the software with example problems provided in the UFC 3-340-02.

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ACRONYMS AND ABBREVIATIONS

AT/FP	Anti-Terrorism and Force Prevention
deg.	degrees
DESR	Defense Explosives Safety Regulation
DoD	Department of Defense
in	inch
ms	milisecond
NAVFAC	Naval Facilities Engineering Systems Command
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NESDAS	NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet
PC	Protection Category
PDC	Protective Design Center
psi	Pounds per Square Inch
SBEDS	Single Degree of Freedom Blast Effects Design Spreadsheet
SDOF	Single Degree of Freedom
UFC	Unified Facilities Criteria

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1.0 INTRODUCTION

This report is intended to act as a user manual for the NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet (NESDAS) Version 2, a software tool developed by the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC or simply EXWC), for the analysis of the dynamic response of single-degree-of-freedom (SDOF) systems to an applied load. The primary intent of this software is to model the response of the structural elements of a protective construction facility under the blast loads expected from an adjacent explosion, in the evaluation of explosive safety for the US Department of Defense (DoD).

A number of software applications currently exist for the prediction of the response of SDOF systems under blast loads (e.g. the SBEDS software [1]) developed by the Protective Design Center (PDC)). However, these software applications were developed with the intention of supporting blast analysis of structures for Anti-Terrorism and Force Prevention (AT/FP) design, and subsequently rely on a number of methodologies and assumptions which are not fully compliant with current DoD guidance and criteria for explosive safety, defined in the Defense Explosive Safety Regulations (DESR 6055.09 [2]) and the Unified Facilities Criteria (UFC) 3-340-02 "Structures to Withstand the Effects of Accidental Explosions" [3]. Additionally, evolving information technology structures within the Navy result in restrictions on software applications that can be installed on government-issued workstations, leading to restrictions on accessibility of such software applications on the machines available to EXWC personnel.

To address these constraints, and to provide greater capability to EXWC personnel in tailoring the software to its specific mission needs, EXWC developed the NESDAS software tool for conduction of dynamic SDOF analysis as needed for performance of protective construction analysis, in their role as the Navy's Technical Warrant Holder and Engineering Agent for blast-resistant structural engineering [4]. The first version of this software tool was originally developed in March 2023. The tool was updated to add additional options and capabilities, and released as NESDAS Version 2. This version of the software is the one detailed in this user manual.

The NESDAS software tool is a macro-enabled Microsoft Excel worksheet. The user inputs values into the spreadsheet based on the parameters determined for a given SDOF system (calculated using design guidance provided within UFC 3-340-02 or other methodologies), using the normal user interface for Microsoft Excel. Algorithms written in Visual Basic embedded within the software then allow for dynamic analysis of the system, and export of the input values and results for integration into technical reports and other records produced by EXWC for analysis, evaluation and endorsement of protective construction for the DoD.

This report details the user interface for the software, provides a description of the analytical methods used by the software, including major assumptions and restrictions of the methodologies, and includes a validation study for the software, comparing its results to those provided in example problems described in the UFC 3-340-02.

2.0 USE OF NESDAS SOFTWARE

This chapter discusses the use of the NESDAS software tool for dynamic analysis of single-degree-of-freedom systems, including the user interface, needed input values, and interpretation and processing of results.

The software tool is accessed by opening the NESDAS file in Microsoft Excel, which will launch the software and take you to the Input worksheet. Note that the software relies on the use of macros embedded within the Excel worksheet, which may be disabled by default on some workstations. This will be indicated by a yellow warning banner at the top of the worksheet stating “SECURITY WARNING: Application add-ins have been disabled”. Clicking on the “Enable Content” button should enable the macros and allow use of the software (See Figure 2-1)

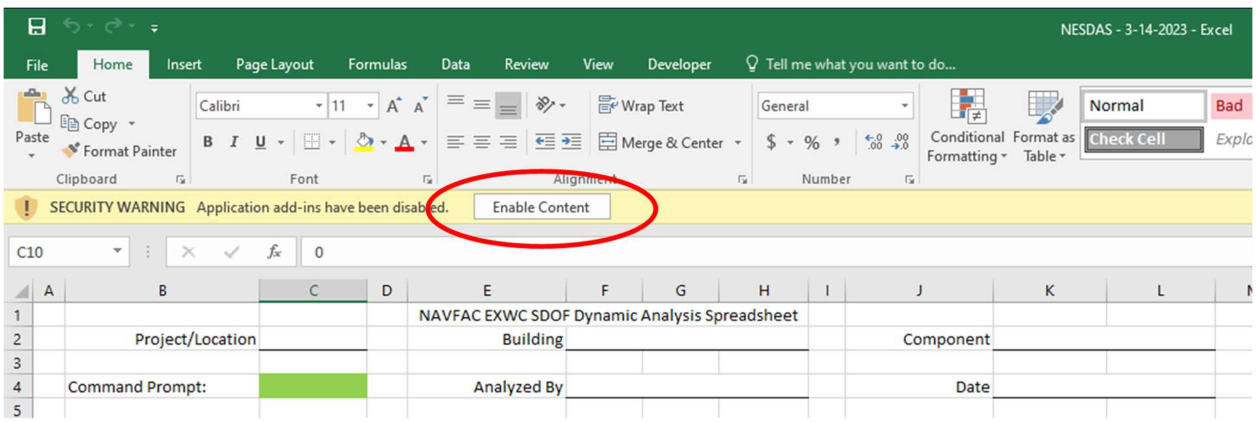
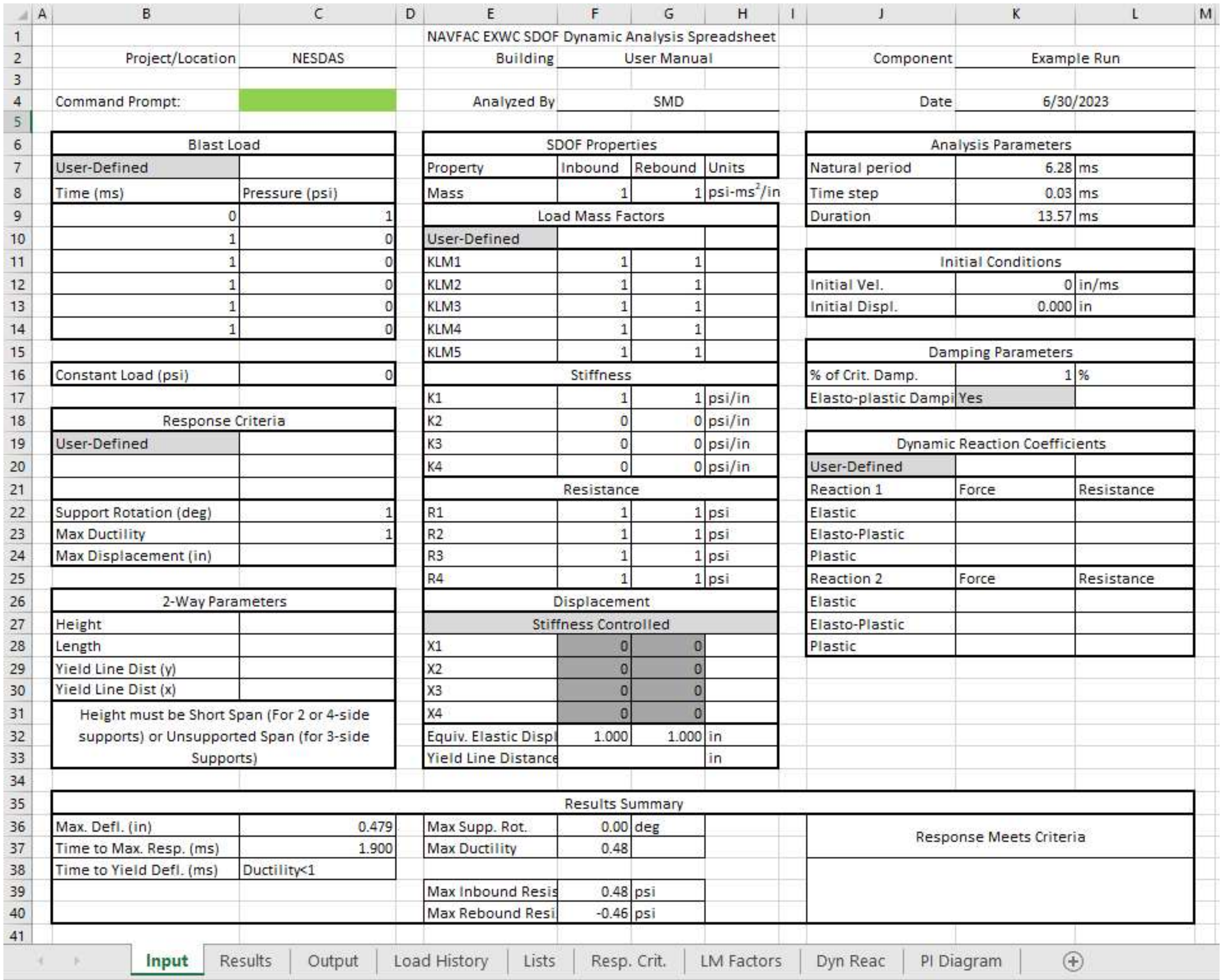


Figure 2-1 Enable Content Button to Allow Execution of Macros within NESDAS Software

2.1 INPUT WORKSHEET

The “Input” worksheet within the NESDAS tools contains all user-input entries required for use of the software, with the exception of the load-history record if the user chooses to use that option (See Section 2.1.1 and 2.4 below). The data on this worksheet is the first of the two pages exported by the software if the user selects the “Print Results” command prompt (See discussion below).

The first rows of the spreadsheet include entries for description of the analyzed scenario, including Project/Location Name, Building Name, Component Name, Name of Individual Performing the Analysis, and Date. Note that the Date entry is auto-populated with the current date whenever the user runs the dynamic analysis function. (See Figure 2-2)



1	NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet	
2	Project/Location	NESDAS
2	Building	User Manual
2	Component	Example Run
4	Command Prompt:	
4	Analyzed By	SMD
4	Date	6/30/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	1
1	0
1	0
1	0
1	0
1	0
Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	1
Max Ductility	1
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	
Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)	

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	1	1	psi-ms²/in
Load Mass Factors			
User-Defined			
KLM1	1	1	
KLM2	1	1	
KLM3	1	1	
KLM4	1	1	
KLM5	1	1	
Stiffness			
K1	1	1	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	1	1	psi
R2	1	1	psi
R3	1	1	psi
R4	1	1	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ	1.000	1.000	in
Yield Line Distance			in

Analysis Parameters		
Natural period	6.28	ms
Time step	0.03	ms
Duration	13.57	ms
Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in
Damping Parameters		
% of Crit. Damp.	1	%
Elasto-plastic Dampi	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

Results Summary				
Max. Defl. (in)	0.479	Max Supp. Rot.	0.00 deg	Response Meets Criteria
Time to Max. Resp. (ms)	1.900	Max Ductility	0.48	
Time to Yield Defl. (ms)	Ductility<1			
		Max Inbound Resis	0.48 psi	
		Max Rebound Resi	-0.46 psi	

Figure 2-2 Input Worksheet of NESDAS Software

The entry rows also include the command prompt for execution of the functions within the software. All commands are selected by choosing them from the dropdown list in Cell C4 (highlighted in green). These include:

- Run Analysis: Executes the SDOF analysis based on the user input, and calculates the dynamic response history of the component
- Print Results: Prints the output from a completed analysis as a PDF file. This includes a record of the user-input values and results from the completed analysis, as well as a record of plots showing displacement, load and resistance-time history from the analysis. (See Figure 2-3).

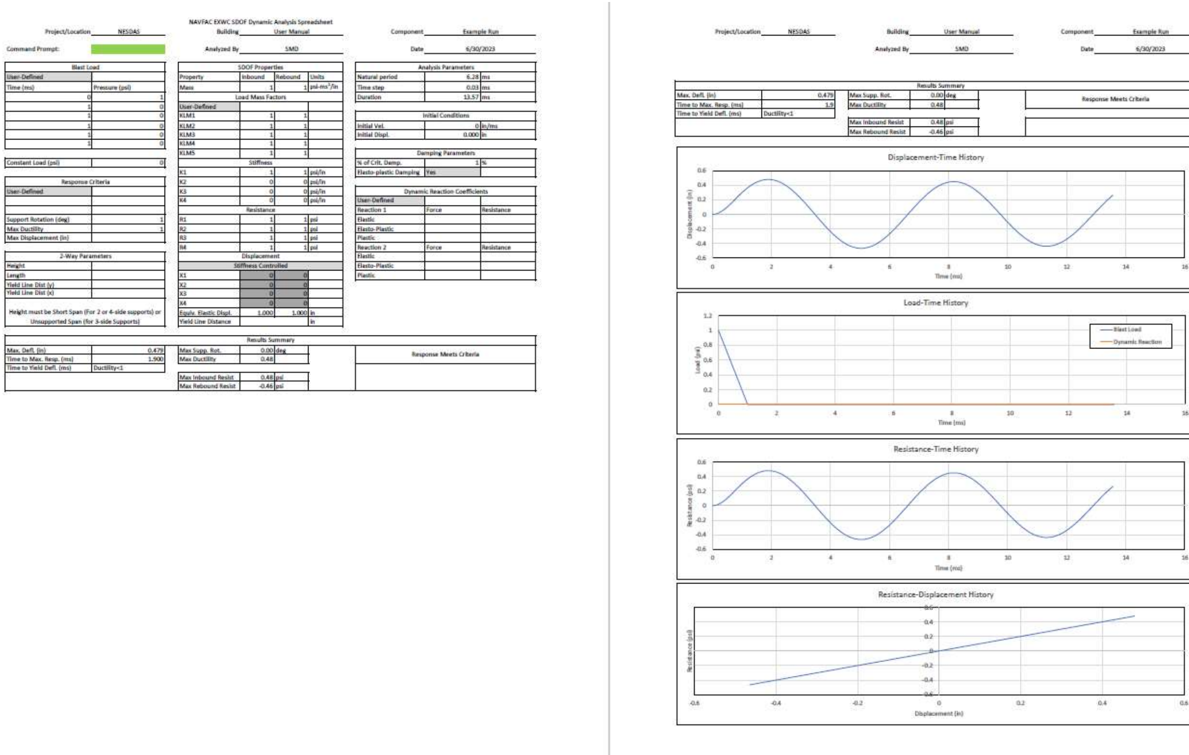


Figure 2-3 Output Results Files from NESDAS Software

- Save Input: Records the input values from the component as a text file for later import into the software.

- Open Input: Retrieves a previously saved input text file from the software, and populates the input values into the spreadsheet for further analysis/use.

- Export Dyn Reactions: Records the dynamic reactions calculated for the SDOF-element as a text file for use in calculating load history on supporting elements (See Section 3.5).

- Export Comb. Load: Records the combined effect of the dynamic reactions of the SDOF element and the directly-applied loads on the face of a supporting element as a text file for use in calculating load history on supporting elements. Selection of this command will launch a user-input form (See Figure 2-4) that prompts the user for details on the span of the supported element(s), the width of the blast-exposed face of the supporting element, which dynamic reaction history to use, and whether or not the supported element is a cantilevered member. These parameters are used in the determination of the combined pressure-time history that is calculated for use in the later analysis of the supporting element (See Section 3.5 for further details).

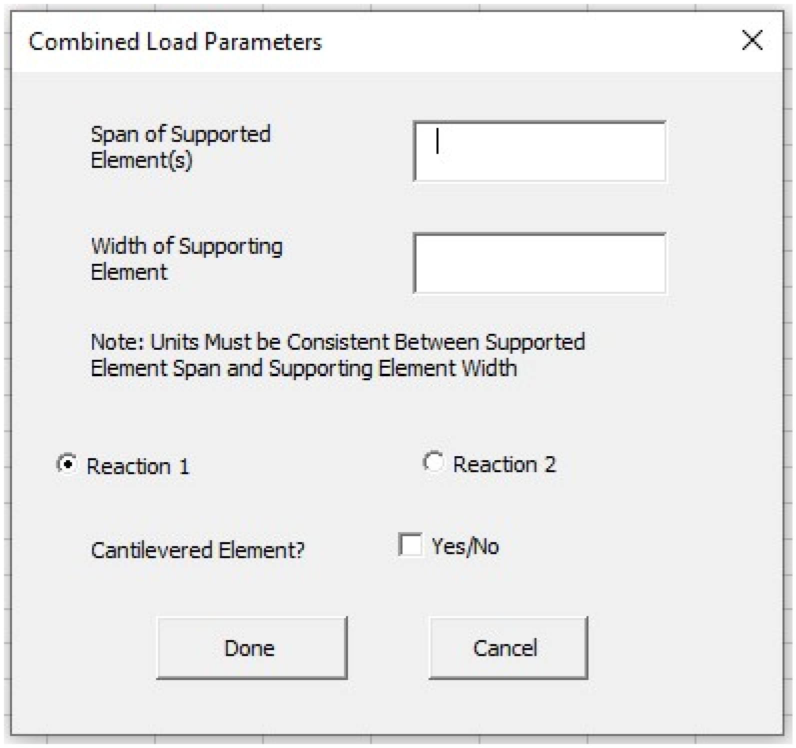


Figure 2-4 User Input Form for Export Combined Load Command Option

- Import Load History: Retrieves a previously saved load-history text file (created via the "Export Dyn Reaction" or "Export Comb. Load" option) and populates entries into the "Load History" Spreadsheet for analysis of other SDOF components.

- Generate P-I Diagram: Generates a P-I Diagram based on the input SDOF properties and response criteria (See Section 2.7)

The remaining data entry blocks include all the input values that the user needs to provide for analysis of an equivalent SDOF system. These entry blocks are detailed below. Note that all data entry blocks include a description of the assumed units for those entries (e.g. psi) if applicable. User-input values must be consistent with these assumed units for the analysis to produce accurate results.

2.1.1 Blast Load

This entry block defines the dynamic load to be applied to the SDOF system. There are two options currently available for use, selected from the dropdown menu in Cell B7:

- User-Defined: With this option, the user inputs the pressure-time history for the SDOF system into the cells in the Applied Load data entry block below. The load-pressure history for the analysis is then interpolated between the user-input values. Note that all entry cells must be filled, and the time history record must not include decreasing values. For ease of use, cells in lower rows are set to automatically duplicate entries above, to enable successful execution of the analysis if fewer entry points are defined in the design blast load.

- Load-History File: With this option, the user can define a more complex load-time history file, by inputting a pressure-time record into the "Load History" worksheet. (See Section 2.4 below).

The load entry also includes an option for the user to input a constant load on the system. Load values input into this entry (Cell C16) are assumed to be present throughout the full considered history of the element, including prior to the arrival of the load (such that the element has already reached the expected static deflection due to this load). This entry is most commonly used to account for gravity loading on the element, but can represent any constant load. Note that the constant load is only used by the software if the "User-Defined" load history option is utilized; this value is not utilized if the load is input via the "Load History Worksheet".

2.1.2 Response Criteria

The Response Criteria entry block defines the performance criteria against which the results of the dynamic analysis will be compared for assessment of whether the component is deemed to be adequate. There is a drop down menu in Cell B19 to determine how the response criteria are defined, with eight options:

- User-Defined: With this option, the user manually inputs all desired performance criteria into the entry cells in the block, including maximum support rotation, maximum ductility, and maximum displacement (if applicable). This option should be used if the analyzed scenario cannot be defined using the pre-defined response criteria options, such as if there are additional scenario-specific constraints on the allowable response of the structure, or if the structure's configuration is not consistent with one of the available auto-populating options.

- Concr. Slab, Concr. Beam/Column, Concr. Flat Slab, Steel Beam/Plate, Cold-Formed Steel, Reinf. Masonry, Precast Concrete: Selection of any of these seven options will cause the spreadsheet to auto-populate the Response Criteria entry block below. These response criteria entries are taken from the criteria in UFC 3-340-02, based on the configuration and the selected protection category (PC) of the component to be analyzed. The assumed configuration is selected from drop-down menus automatically generated by the spreadsheet in Cell B20 (if applicable). The applicable protection category is selected from the drop-down menu in Cell B21. See further details below.

2.1.2.1 Component Configuration Selection

The applicable response criteria for many protective construction elements is a function of both the protection category, but also of additional aspects related to the specific configuration of the component (i.e. Cold-Formed Steel Panels can achieve higher support rotations and ductility if supported in a manner that allows the development of tensile membrane action). These configurations are selected from the drop-down menu automatically generated in Cell B20 if one of the specific component options is selected for analysis (See Section 2.1.2 above). The options corresponding to the different components are briefly described below:

- Concr. Slab: The performance criteria for Concrete Slabs are determined based on the user's selection from the four available auto-populating configuration options: 1) No Shear Ties Present and No Tensile Membrane Action 2) Shear Ties Present and No Tensile Membrane Action 3) Tensile Membrane Action (with or without Shear Ties) and 4) Lacing Present.

- Concr. Beam/Column: The performance criteria for Concrete Beams and Exterior Columns are determined based on the user's selection from the three available auto-populating configuration options: 1) Beams with No Lateral Restraint 2) Beams with Lateral Restraint provided and 3) Exterior Columns.

- Concr. Flat Slab: The performance criteria for Concrete Flat Slabs are determined based on the same auto-populating configuration options defined for Concrete Slabs (See above).

- Steel Beam/Plate: The performance criteria for Steel Beams, Beam-Columns and Plates are based on the Protection Category assigned to the element, and no additional selection of component configuration is required.

- Cold Formed Steel: The performance criteria for Steel Joists, Joist Girders, and Cold-Formed Steel Panels Concrete Slabs are determined based on the user's selection from the four available auto-populating configuration options: 1) Joists whose design is Controlled by Shear 2) Joists whose design is controlled by Flexural Response 3) Cold-Formed Steel Panels with Tension Membrane Action and 4) Cold-Formed Steel Panels without Tension Membrane Action.

- Reinf. Masonry: The performance criteria for Reinforced Masonry components are based on the Protection Category assigned to the element, and no additional selection of component configuration is required.

- Precast Concrete: The performance criteria for Precast Concrete Members are determined based on the user's selection from the three available auto-populating configuration options: 1) Non-Prestressed Flexural members 2) Prestressed Flexural members and 3) Compression Members

Note that the drop down list in excel includes four possible entries for all cases even when there are fewer valid options (i.e., there are blank entries listed in the drop-down menu). No auto-populating response criteria are available for these blank entries; selection of one of these blank entries will generate an error message "Value Must Be Selected from Dropdown List", and the specimen will over-write the cell with the first valid option for the component.

Note that there are additional constraints on specimen configuration prescribed by UFC 3-340-02 that cannot be captured in the spreadsheet due to its lack of explicit consideration of other potential parameters. E.g., Concrete slabs intended for close-in loading cannot be designed without shear ties). It is the responsibility of the user to ensure that such constraints are considered in their design of protective construction for explosive safety.

2.1.2.2 Protection Category Selection

Determination of the applicable UFC 3-340-02 response criteria using the auto-populating functionality within NESDAS is also dependent on the selection of the Protection Category assigned to the component (PC1, PC2 or PC3), selected by the user from the dropdown menu in Cell B21. Note that for many of the potential components, response criteria are not defined by the UFC 3-340-02 for all potential protection categories. (E.g., response criteria for steel beams are only defined for PC1 and PC2). Selection of a higher protection category for such components will result in the software assigning the response criteria associated with the next lowest defined protection category. (I.e., user selection of PC3 for a steel beam will result in the software applying the performance criteria associated with PC2).

Note that any response criteria entry which is left blank will not be considered by the software in determination of whether the component is considered to meet criteria.

2.1.3 2-Way Parameters

This entry block defines the parameters used by the software in determining the appropriate factors to apply if the dynamic load-mass factors and dynamic response coefficients are determined using the auto-population options for those functions (See Sections 2.1.4.2 and 2.1.8). The use must input values for the Height and Length of the 2-Way component, as well as the corresponding Yield Line Distances.

Note that the assignation of these values must be consistent with the configuration of these values defined in UFC 3-340-02 Figures 3-4 through 3-17. I.e., "Height" must be the dimension corresponding to the shorter span (for a 2-way element with two adjacent supported sides, or four supported sides) or to the un-supported span (for a 2-way element with three supported sides). The yield line distance "y" must be the distance to the yield line in the direction parallel to the Height.

Input of parameters using a different labeling convention will result in incorrect values being generated by the software.

Note also that the parameters calculated using these data entries are based only on the ratios between the different values. Hence, the dimensions can be input in whatever units the user prefers; however, these units must be consistent between all four values for accurate calculation of the dependent parameters.

2.1.4 SDOF Properties

The SDOF Properties entry block includes data entries for characterizing the structural response of the analyzed component to the design blast loads. The entries requiring user-input are detailed below.

Refer to Section 2.7 below for full details on the software's use of the assumed SDOF properties in calculation of the dynamic response of the SDOF system.

Note that for all entries, the spreadsheet assumes symmetry of response in the inbound and rebound phase by default, and will auto-populate the rebound values based on the input values for inbound response. If the user intends to analyze an asymmetrically responding component, the rebound values can be manually over-written as needed.

Note that the rebound values input into the spreadsheet are assumed to be positive in the rebound direction. E.g. a rebound resistance of 4 psi is considered as 4 psi of resistance in the direction opposite of the applied loads. The user should not input negative values for the SDOF response in rebound.

2.1.4.1 Mass

The first entry sub-block in the SDOF Properties entry block is the mass entry, where the user must input the inertial mass of the system. Note that both mass terms must be greater than zero for successful execution of the analysis.

2.1.4.2 Load-Mass Factors

The next entry sub-block defines the dynamic load-mass factors for the SDOF component. There are eight options currently available for use, selected from the drop-down menu in Cell E10.

- User-Defined: The user manually inputs all dynamic load-mass factors into the cells in the sub-block based on the properties of the analyzed components. Note that all entries must be populated with data values greater than zero for successful execution of the analysis. For ease of use, cells in lower rows are set to automatically duplicate entries above, to enable successful execution of the analysis if fewer factors are needed to describe the system response (i.e. if the structure has fewer than 5 phases of response).

- Simply Supported, Fixed-Fixed, Cantilever, and Propped Cantilever: Selection of any of these options (based on the described support conditions for the analyzed 1-way structural element) from the drop-down menu will cause the spreadsheet to auto-populate the required entries below, based on dynamic load-mass factors specified by UFC 3-340-02 Table 3-12. Note that these factors are also dependent on the load shape applied to the element (i.e. a point load or uniform load). Selection of this load shape is done via the drop-down menu created in Cell F10 when one of the above support conditions is selected. Other load shapes (e.g. a highly non-uniform distributed load) may require the use of alternate load-mass factors, which must be manually calculated and input by the user using the User-Defined option.

- 2-Side Supported, 4-Side Supported: Selection of any of these options (based on the described support conditions for the analyzed 2-way structural element) from the drop-down menu will cause the spreadsheet to auto-populate the required entries below, based on dynamic load-mass factors specified by UFC 3-340-02 Table 3-13. Note that these factors are also dependent on the flexural restraint of the supports (i.e. whether the perimeters supports are All Fixed or All Pinned). Selection of this restraint is done via the drop-down menu created in Cell F10 when one of the above support conditions is selected.

- 3-Side Supported: Selection of this options (based on the described support conditions for the analyzed 2-way structural element) from the drop-down menu will cause the spreadsheet to auto-populate the required entries below, based on dynamic load-mass factors specified by UFC 3-340-02 Table 3-13. Note that these factors are dependent on the flexural restraint of the supports, as with the previous 2-Way elements described above. However, for 3-side supported elements with fixed edges, the appropriate load-mass factors are also dependent on the location of the initial plastic hinge (i.e., whether the initial plastic hinge forms at the supports of the symmetrically-supported span, or in the support of the asymmetrically-supported span). Selection of the support restraint, and location of initial plastic hinge (if applicable) is done via the drop-down menu created in Cell F10 when the 3-side supported condition is selected.

Note that the auto-populated entries for 2-way elements are only accurate if the supports are consistent along all supported edges (i.e. all supports are fixed or all supports are pinned). The flexural capacity of the supports must also be symmetric, if applicable. E.g., the negative moment capacity along both short edges of a 4-side supported system with fixed edges must be equal. 2-way elements with inconsistent or asymmetric flexural restraints along their edges require the use of alternate load-mass factors, which must be manually calculated and input by the user using the User-Defined option.

2.1.4.3 Stiffness

The next entry sub-block defines the stiffness values for the analyzed SDOF component during its different phases of response, based on user-calculated values for the expected SDOF system response. Note that all entries must be populated with data values greater than or equal to zero for successful execution of the analysis. For ease of use, cells in lower rows are set to automatically duplicate entries above, to enable successful execution of the analysis if fewer factors are needed to describe the system response (i.e. if the structure has fewer than 4 phases of elastic and elasto-plastic response).

Note that the component is assumed to deform as a fully-plastic element for conditions that exceed the ultimate resistance defined for the component (See Section 2.1.4.4 below). I.e. the stiffness is automatically assumed to be equal to zero by the algorithm for any response that exceeds the highest resistance specified for the component.

Note that these values are only utilized by the software if the user conducts a stiffness-controlled analysis, which is the default option selected by the software. If the user opts to conduct a displacement-controlled analysis (selected using the dropdown menu in Cell E27), these stiffness values are not utilized in any software calculations (the cells associated with these values will be grayed out in such an analysis, to note their non-use by the software).

2.1.4.4 Resistance

The next entry sub-block defines the limiting resistance values for the analyzed SDOF component during its different phases of response, based on user-calculated values for the expected SDOF system response. Note that input resistance values must be monotonically increasing for the software's solver algorithm to properly function (i.e., R2 must be greater than or equal to R1, and R3 must be greater than or equal to R2). Note also that all entries must be populated with data values for successful execution of the analysis. For ease of use, cells in lower rows are set to automatically duplicate entries above, to enable successful execution of the analysis if fewer factors are needed to describe the system response (i.e. if the structure has fewer than 4 phases of elastic and elasto-plastic response).

2.1.4.5 Displacement

The next entry sub-block defines the displacement values for the analyzed SDOF component during its different phases of response, corresponding to the different individual user-input resistance values specified previously. These values are only utilized by the software if the user conducts a displacement-controlled analysis, (selected using the dropdown menu in Cell E27). This option is typically done for components that undergo structural softening, such that their resistance/displacement response cannot be modeled using the software's default stiffness algorithm. If the software is not set to conduct a displacement-controlled analysis, displacement values are not utilized in any software calculations (the cells associated with these values will be grayed out in such an analysis, to note their non-use by the software).

Note that the initial displacement values (in both inbound and rebound response) must be greater than zero, and that input displacement values must be monotonically increasing for the software's solver algorithm to properly function (i.e., X2 must be greater than or equal to X1, and X3 must be greater than or equal to X2). Note also that all entries must be populated with data values for successful execution of the analysis. For ease of use, cells in lower rows are set to automatically duplicate entries above, to enable successful execution of the analysis if fewer factors are needed to describe the system response (i.e. if the structure has fewer than 4 phases of elastic and elasto-plastic response).

2.1.4.6 Additional Parameters

The next entry in the SDOF Property entry block consists of the equivalent elastic displacement (used in determination of system ductility, and time to yield deflection, See Section 2.1.9). This equivalent elastic displacement is automatically calculated by the spreadsheet based on the user-input SDOF resistance and stiffness/displacement properties (depending on whether the system is set to stiffness or displacement control), and design guidance in UFC 3-340-02 Section 3-14.2. Note that the calculated equivalent elastic displacement value is based on the full positive-stiffness portion of the component's response; I.e., resistance-displacement values associated with the perfectly plastic or softening phase of the component response are ignored. This value can be manually overwritten by the user if desired based on the specific component to be analyzed.

The next entry in the SDOF Property entry block is the yield line distance for the component, used by the software in determination of maximum support rotation (See Section 2.1.9). This value must be input by the user based on the considered component.

2.1.5 Analysis Parameters

The Analysis Parameters entry block is used by the software to determine constraints on the time period of the computed SDOF solution. The natural period is automatically calculated by the spreadsheet as $2 * \pi * \sqrt{M/K}$, where M represents the inbound elastic mass of the structure (including the elastic load-mass factor) and K represents the inbound elastic stiffness of the structure (defined either by K1, or by R1/X1, if the system is set to stiffness or displacement controlled, respectively).

The default time-step (used in the dynamic analysis of the system) is selected as the lower value of 1/30th of the total duration of the applied load, 1/10th of the timestep between individual user-input load values (if the "User-Defined" load input option is selected), or 1/50th of the natural period of the component. Calculated time steps below 0.01 ms or above 0.1 ms are set at 0.01 and 0.1 ms, respectively. This value may be overwritten by the user if an alternate timestep is desired.

The total duration of system response is set by default at a value equal to the total duration of the applied load, plus two times the component's natural period, to capture potential post-load behavior. This value may also be overwritten by the user if a lesser or greater analyzed duration is desired.

2.1.6 Initial Conditions

The Initial Conditions entry block is used by the software to define the initial velocity and displacement of the component prior to the arrival of the blast loads. If needed, the user can input an initial velocity and/or initial displacement for the component, as calculated by the user for the specific considered scenario.

The spreadsheet is configured to automatically calculate the initial displacement of the component based on the constant load on the element if present (defined by the user in the Applied Load entry block). This cell will display a message of "Unstable" if the constant load exceeds the ultimate resistance of the component, such that the element is predicted to collapse under the constant load. The user can overwrite this value if needed, based on the initial conditions for the specific scenario being considered.

2.1.7 Damping Parameters

The Damping Parameters entry block is used by the software to determine the assumed damping to apply to the component during the dynamic analysis, expressed as a percentage of critical damping (See discussion in Section 3.4 below). This value must be selected by the user based on the component being evaluated; UFC 3-340-02 Section 3-19.2.3 recommends a value of 5% be used for steel structures, and 1% be used for concrete structures.

The user can set the software to consider the effects of damping during the elastic and elasto-plastic response of the component by choosing "Yes" from the "Elasto-Plastic Damp" drop-down menu in Cell K17. The software can also be set to only consider the effects of damping during the elastic phase of the component response by selecting "No" from the drop-down menu; this option is enabled for improved comparison with other SDOF software applications which may only consider elastic damping. Regardless of option selected, no damping is assumed during the fully plastic phase of the component response.

2.1.8 Dynamic Reaction Coefficient

The Dynamic Reaction Coefficient entry block allows the user to input values to be used in calculation of the dynamic reactions of the component for estimation of applied loads to supporting elements (See discussion in Sections 3.2 and 3.5). Dynamic reaction coefficients are calculated for both support reactions of 1-way elements, and both edges of 2-way elements. Note that for some configurations, these reactions are symmetric at both supports. For auto-populated elements whose coefficients differ, the support corresponding to the different coefficients is described in Cells J21 and J25.

Note that use of the dynamic reaction history in prediction of the loading applied to a supporting protective construction element is not currently considered to be compliant with the design guidance in UFC 3-340-02, and should not be used in structures intended to be evaluated for compliance with that criteria. There are eight options currently available for use, selected via the drop-down menu in Cell J20:

- User-Defined: The user must input all desired dynamic reaction coefficients into the Dynamic Reaction Coefficient entry block below, based on the coefficients determined for the specific component to be analyzed. Note that any entries left blank will be assumed to be zero by the software, and may result in an under-prediction of the applied loading.

- Simply Supported, Fixed-Fixed, Cantilever and Propped Cantilever: Selection of any of these options (based on the described support conditions for the analyzed 1-Way structural element) from the drop-down menu will cause the spreadsheet to auto-populate the required data entries below, based on dynamic reaction coefficients provided in UFC 3-340-01 Table 11-3 and 11-4. Note that these factors are also dependent on the load shape applied to the element (i.e. a point load or uniform load). Selection of this load shape is done via the drop-down menu created in Cell K20 when one of the above support conditions is selected. Other load shapes (e.g., a highly non-uniform distributed load) may require the use of alternate dynamic reaction coefficients, which must be manually calculated and input by the user using the User-Defined option.

- 2-Side Supported, 3-Side Supported, and 4-Side Supported: Selection of any of these options (based on the described support conditions for the analyzed 2-Way structural element) from the drop-down menu will cause the spreadsheet to auto-populate the required data entries below, based on dynamic reaction coefficients provided in UFC 3-340-01 Table 11-5 through 11-10. Note that these factors are also dependent on the flexural restraint provided to the element (i.e. all supports fixed or all supports pinned). Selection of this load shape is done via the drop-down menu created in Cell K20 when one of the above support conditions is selected. Other restraint conditions (e.g., a 4-side supported slab with flexural restraint along 3 sides) will require the use of alternate dynamic reaction coefficients, which must be manually calculated and input by the user using the User-Defined option.

2.1.9 Results Summary

The Results Summary entry block summarizes the key results from the dynamic response of the system once the user runs the analysis of an SDOF system. These results are described below:

- Max. Defl. (in): The Maximum Deflection exhibited by the element in response to the applied loads. This value represents the maximum absolute deflection exhibited by the component. I.e., the spreadsheet will report the maximum rebound deflection if that value is calculated to exceed the maximum inbound deflection. If this occurs, the spreadsheet will also display an informational note "Maximum Response in Rebound Phase" in Cell J39.

- Time to Max Resp. (ms): The initial time step at which the SDOF system experiences the maximum deflection described previously

- Time to Yield Defl. (in): The initial timestep at which the SDOF system is considered to reach yield (assumed to be when the system exceeds the Equivalent Elastic Displacement defined in the SDOF Properties entry block). This value can be used for calculation of the strain rate of the system. If the SDOF system does not reach the equivalent elastic displacement under the applied loads, this entry displays a message of "Ductility<1", in which case the strain rate should be based on the Maximum Deflection and Time to Max Response calculated previously. If the SDOF system experiences multiple distinct displacement peaks prior to reaching its maximum deflection, the entry displays a message of "Multiple Peaks". In such a case, the user must manually investigate the magnitude and timing of the different peaks to determine the controlling strain rate for the element's calculated dynamic response.

- Max Supp. Rot.: The Maximum Support Rotation experienced by the element in its dynamic response, expressed in degrees. This support rotation is calculated based on guidance in UFC 3-340-02 Chapter 3, as the arctangent of the Maximum Deflection/Yield Line Distance, as defined in the SDOF Properties entry block.

- Max Ductility: The Maximum Ductility exhibited by the element in its dynamic response, calculated as the ratio of the Maximum Deflection and the Equivalent Elastic Displacement defined in the SDOF Properties Entry Block. This includes a check on the maximum ductility of the element in both the inbound and rebound response. If the calculation determines the maximum ductility is in the rebound phase, the spreadsheet will also display an informational note "Maximum Ductility in Rebound Phase" in Cell J39.

- Max Inbound Resist: The Maximum Resistance exhibited by the element during the inbound phase of its response to the applied loads.

- Max Rebound Resist: The Maximum Resistance exhibited by the element during the rebound phase of its response to the applied loads.

- Performance Criteria Compliance: This cell (J36) displays a summary of whether the system meets the performance criteria defined in the Response Criteria Entry Block. Four potential messages are displayed:
  - "No Criteria Specified": Displayed if the user has not input any response criteria in the Response Criteria entry block
  - "Response Meets Criteria": Displayed if the dynamic response calculated for the SDOF system does not exceed any of the response criteria defined in the Response Criteria entry block.
  - "Response Does Not Meet Criteria": Displayed if the dynamic response calculated for the SDOF system exceeds any of the response criteria defined in the Response Criteria entry block. The cell is also highlighted in red to emphasize the condition.
  - "Current Input Does Not Match Output, Re-Run Analysis": Displayed if changes have been made to the user-input values used in the SDOF analysis since the analysis has been run, such that the displayed results are no longer consistent with the displayed input values. The cell is also highlighted in yellow to emphasize the condition. Selecting the "Run Analysis" option from the command prompt should clear this message.
- Warning Messages: This cell (J38) displays various potential warning messages that indicate that the values reported by the spreadsheet may be inaccurate and/or not fully consider all relevant aspects of the components response. These conditions are not inherently indicative of invalid results from the software, but should be evaluated by the user for assessment of their impact on the validity of the results and the adequacy of the component. Presence of one of these messages will also cause the cell to be highlighted in yellow to emphasize the condition. Seven potential warning messages are displayed:
  - "2-Way Parameters Must Be Defined": Displayed if the user has selected one of the auto-populating options for load-mass factors or dynamic reaction coefficients involving 2-way elements, but has not fully defined the 2-Way parameters in the relevant entry block, resulting in potentially inaccurate factors corresponding to those coefficients.
  - "Response Criteria do not Match Dropdown Selection", "Load-Mass Factors do not Match Dropdown Selection", "Dynamic Reaction Factors do not Match Dropdown Selection": Displayed if the user has selected one of the auto-populating entries for the Response Criteria, Load Mass Factors, or Dynamic Reaction Coefficients, but has later changed those values, resulting in potential inconsistencies between the calculated results and assumed conditions.

- “Load-Mass Factor Selection Does Not Match Dynamic Reaction Selection”: Displayed if the user has selected one of the auto-populating entries for both the Load Mass Factors and Dynamic Reaction Coefficients, but those inputs are inconsistent (e.g., the Load-Mass Factors are based on a Simply Supported beam, while the Dynamic Reaction Coefficient are based on a Fixed-Fixed beam), such that one of the parameters is likely inconsistent with the expected system behavior.

- “Max Defl Exceeds Max User-Input Displacement”: Displayed if the maximum deflection calculated by the system exceeds the maximum displacement value input by the user into the Displacement entry block, when running a displacement-controlled analysis. This can lead to inaccuracies if the software’s default assumption of perfectly plastic displacement after reaching the maximum deflection is inconsistent with the expected load-displacement pattern for the component.

- “Maximum Response in Rebound Phase”, “Maximum Ductility in Rebound Phase”: Displayed if the maximum deflection or ductility of the system occurs in the rebound phase of the element, which may necessitate additional consideration to ensure adequate performance of the component if there are potential asymmetries in its capacity/connections/etc.

- “Damping Coefficient Exceeds UFC 3-340-02 Recommendation for Component Type”: Displayed if the user-input value for percent of critical damping exceeds the values recommended in the UFC 3-340-02 for the selected component type (e.g. 1% for concrete components, See Section 2.1.7)

2.2 RESULTS WORKSHEET

The results worksheet provides a further summary of the results of the SDOF analysis (See Figure 2-5). This includes a reproduction of the Results Summary entry block from the Input worksheet (See Section 2.1.9 above). The worksheet also includes a series of plots displaying the displacement-time history, load-time history (including both the applied load and the dynamic reaction of the system), resistance-time history, and resistance-displacement history of the computed response of the SDOF system. The data on this worksheet is the second of the two pages exported by the software if the user selects the “Print Results” command prompt (See Section 2.1 above).

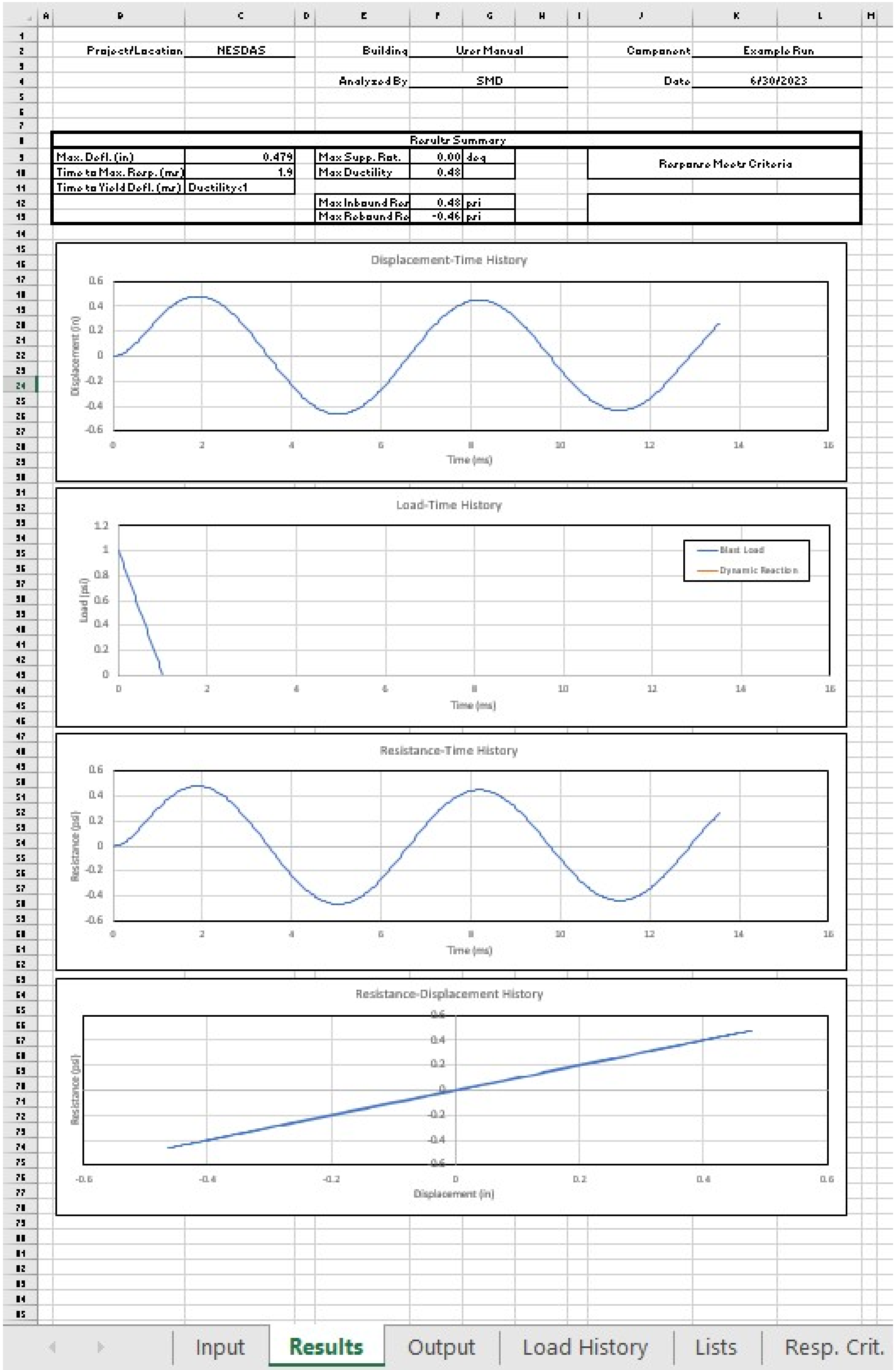


Figure 2-5 Results Worksheet of NESDAS Software

2.3 OUTPUT WORKSHEET

The output worksheet provides a detailed record of the full dynamic history of the SDOF system response to the applied loads (See Figure 2-6). For each timestep considered in the analysis, the Output worksheet displays the total elapsed time, applied load, deflection, velocity, acceleration, current system stiffness, component resistance and the dynamic reaction of the component.

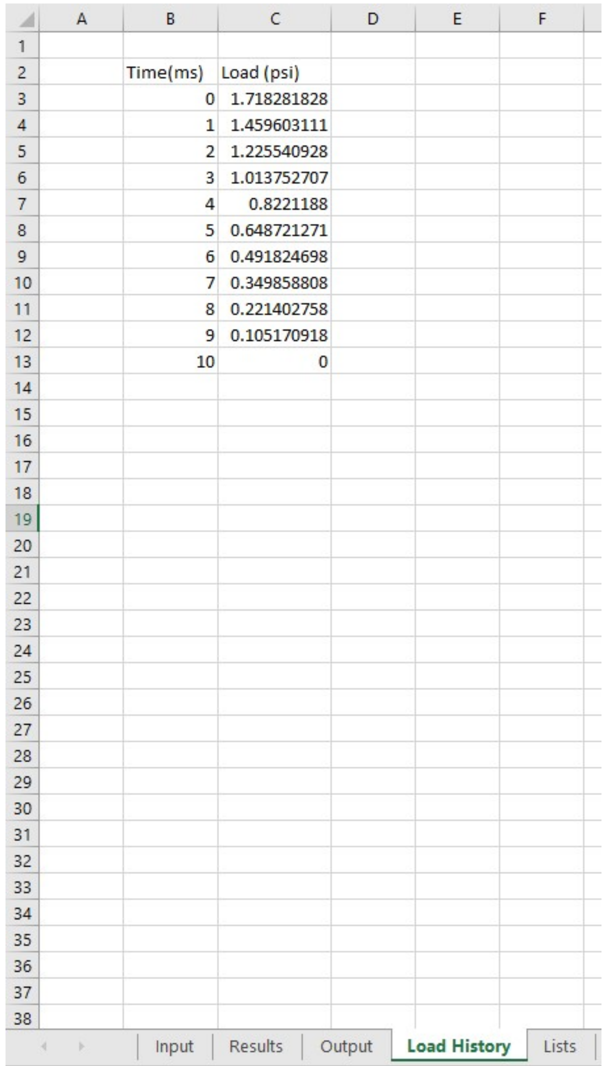
	A	B	C	D	E	F	G	H	I	J	K
1											
2		Time	Load	Deflection	Velocity	Acceleratio	Stiffness	Resistance	Dyn Reac 1	Dyn Reac 2	
3		(ms)	(psi)	(in)	(in/ms)	(in/ms^2)	(psi/in)	(psi)	(psi)	(psi)	
4		0	1	0	0	0.99966678	1	0	0	0	
5		0.03333333	0.96666667	0.00055537	0.03332223	0.96545626	1	0.00055537	0	0	
6		0.06666667	0.93333333	0.00219258	0.06491053	0.92984208	1	0.00219258	0	0	
7		0.1	0.9	0.00486268	0.09529508	0.89323068	1	0.00486268	0	0	
8		0.13333333	0.86666667	0.00852498	0.12444312	0.85565181	1	0.00852498	0	0	
9		0.16666667	0.83333333	0.01313775	0.15232311	0.81714784	1	0.01313775	0	0	
10		0.2	0.8	0.01865822	0.17890495	0.77776215	1	0.01865822	0	0	
11		0.23333333	0.76666667	0.02504263	0.20415997	0.73753906	1	0.02504263	0	0	
12		0.26666667	0.73333333	0.03224632	0.22806101	0.6965238	1	0.03224632	0	0	
13		0.3	0.7	0.04022371	0.25058245	0.65476243	1	0.04022371	0	0	
14		0.33333333	0.66666667	0.04892842	0.27170019	0.61230183	1	0.04892842	0	0	
15		0.36666667	0.63333333	0.05831328	0.29139171	0.56918961	1	0.05831328	0	0	
16		0.4	0.6	0.06833041	0.30963611	0.52547408	1	0.06833041	0	0	
17		0.43333333	0.56666667	0.07893125	0.32641408	0.48120419	1	0.07893125	0	0	
18		0.46666667	0.53333333	0.09006662	0.34170797	0.43642946	1	0.09006662	0	0	
19		0.5	0.5	0.10168678	0.3555018	0.39119996	1	0.10168678	0	0	
20		0.53333333	0.46666667	0.1137415	0.36778123	0.3455662	1	0.1137415	0	0	
21		0.56666667	0.43333333	0.12618008	0.37853365	0.29957913	1	0.12618008	0	0	
22		0.6	0.4	0.13895144	0.38774814	0.25329005	1	0.13895144	0	0	
23		0.63333333	0.36666667	0.15200417	0.39541548	0.20675056	1	0.15200417	0	0	
24		0.66666667	0.33333333	0.16528656	0.4015282	0.16001252	1	0.16528656	0	0	
25		0.7	0.3	0.17874671	0.40608054	0.11312794	1	0.17874671	0	0	
26		0.73333333	0.26666667	0.19233253	0.40906849	0.066149	1	0.19233253	0	0	
27		0.76666667	0.23333333	0.20599183	0.41048977	0.01912791	1	0.20599183	0	0	
28		0.8	0.2	0.21967239	0.41034385	-0.0278831	1	0.21967239	0	0	
29		0.83333333	0.16666667	0.23332199	0.40863194	-0.0748318	1	0.23332199	0	0	
30		0.86666667	0.13333333	0.24688847	0.40535698	-0.121666	1	0.24688847	0	0	
31		0.9	0.1	0.26031981	0.40052364	-0.168334	1	0.26031981	0	0	
32		0.93333333	0.06666667	0.27356418	0.39413834	-0.214784	1	0.27356418	0	0	
33		0.96666667	0.03333333	0.28656997	0.3862092	-0.2609644	1	0.28656997	0	0	
34		1	0	0.29928589	0.37674606	-0.3068243	1	0.29928589	0	0	
35		1.03333333	0	0.31167026	0.36631565	-0.319	1	0.31167026	0	0	
36		1.06666667	0	0.32370027	0.35548543	-0.3308133	1	0.32370027	0	0	
37		1.1	0	0.33536283	0.34426768	-0.3422514	1	0.33536283	0	0	
38		1.13333333	0	0.34664521	0.33267513	-0.3533018	1	0.34664521	0	0	

Input | Results | **Output** | Load History | Lists | Resp. Crit. | LM Factors | Dyn Reac | PI Diagram

Figure 2-6 Output Worksheet of NESDAS Software

2.4 LOAD HISTORY WORKSHEET

The Load History worksheet provides an option for the user to input a full load-time history for the applied load on the SDOF system, if the analysis requires definition of a more complex load-time history than can be described by the Applied Load entry block (See Figure 2-7).



	A	B	C
1			
2		Time(ms)	Load (psi)
3		0	1.718281828
4		1	1.459603111
5		2	1.225540928
6		3	1.013752707
7		4	0.8221188
8		5	0.648721271
9		6	0.491824698
10		7	0.349858808
11		8	0.221402758
12		9	0.105170918
13		10	0

Figure 2-7 Load History Worksheet of NESDAS Software

This load-time history should be input by the user as a series of time-load data pairs, typed into the cells in Columns B and C of the worksheet, copied from the dynamic reactions generated by previous analysis, or otherwise generated by the user. The load-time history can be defined using non-uniform timesteps; however, the timesteps must increase monotonically for successful execution of the software.

The data record input into this spreadsheet will be used by the software in its analysis if the “Load History File” option is selected from the Applied Load drop-down menu in the Input worksheet. The time history used in the SDOF analysis conducted by the software will be interpolated between the time-load data pairs defined in this spreadsheet, based on the time-step defined for the analysis in the Analysis Parameters entry block on the Input worksheet.

2.5 LISTS WORKSHEET

The Lists worksheet is a database of the options corresponding to some of the drop-down menus used within the Input worksheet and the potential warning messages to be displayed in the results summary (See Figure 2-8). The worksheet also includes miscellaneous calculations, including a parameter analyzing the user-input values currently displayed by the spreadsheet, along with the user-input values that were defined during the most recently conducted analysis, for determination of whether the currently-displayed results are consistent with the current input, and derivation of the equivalent elastic displacement for the component. The user should have no need to interact with the Lists worksheet under normal operation of the software; changes made by the user to this worksheets are likely to result in errors during running of the software, and are not recommended.

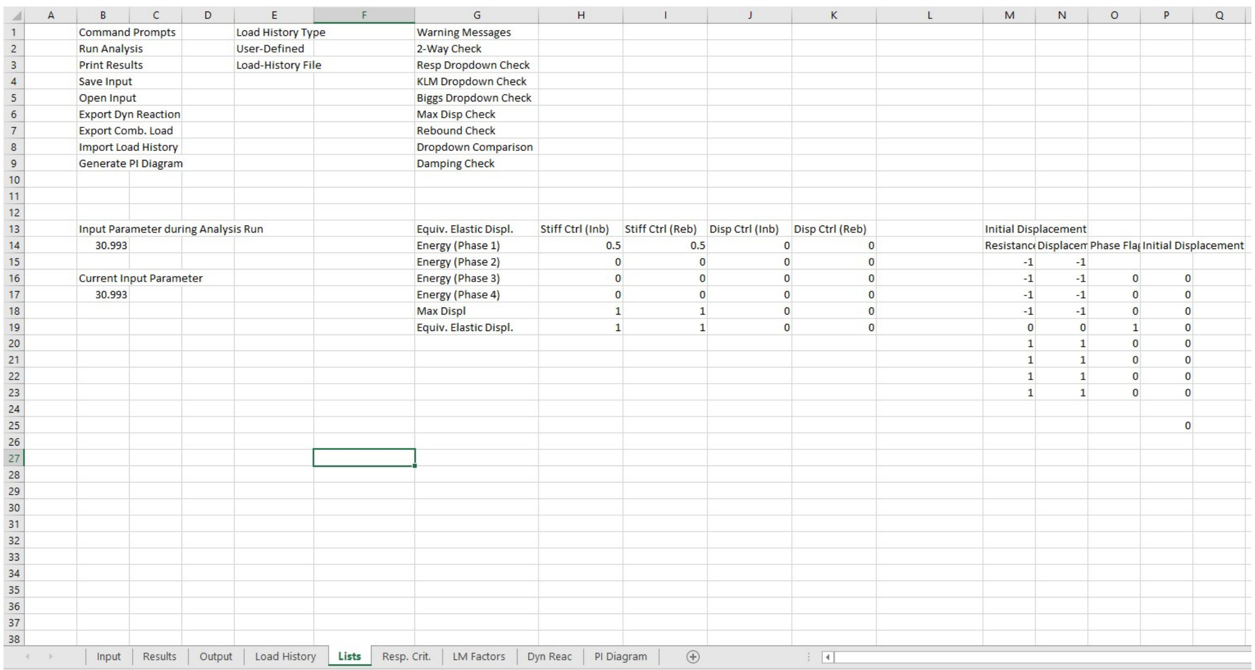


Figure 2-8 Lists Worksheet of NESDAS Software

2.6 RESP. CRIT., LM FACTORS, DYN REAC WORKSHEETS

The Response Criteria, Load-Mass Factors, and Dynamic Reactions worksheets are each databases of the options corresponding to the associated drop-down menus used within their respective entry blocks in the Input worksheet, as well as of the associated values used to auto-populate those entry blocks if selected by the user (See Figure 2-9 below). The user should have no need to interact with these worksheets under normal operation of the software; changes made by the user to these worksheets are likely to result in errors during operation of the software, and are not recommended.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1															
2					Supports	Configuration	Reference	KLM1	KLM2	KLM3	KLM4	KLM5			
4				Analyzed Scenario	Simply Supported	Uniform Load	21	0.78	0.66	0.66	0.66	0.66			
5															
6		Support Conditions	Configuration	Reference Index	KLM1	KLM2	KLM3	KLM4	KLM5		Controlling Yield Line Distance (2-way)			Plastic Load Mass Factor	
7		User-Defined		11							0			0.666649	
8		Simply Supported	Uniform Load	21	0.78	0.66	0.66	0.66	0.66						
9		Simply Supported	Point Load	22	0.49	0.33	0.33	0.33	0.33						
10		Fixed-Fixed	Uniform Load	31	0.77	0.78	0.66	0.66	0.66						
11		Fixed-Fixed	Point Load	32	0.37	0.33	0.33	0.33	0.33						
12		Cantilever	Uniform Load	41	0.65	0.66	0.66	0.66	0.66						
13		Cantilever	Point Load	42	0.24	0.33	0.33	0.33	0.33						
14		Propped Cantilever	Uniform Load	51	0.78	0.78	0.66	0.66	0.66						
15		Propped Cantilever	Point Load	52	0.43	0.49	0.33	0.33	0.33						
16		2-Side Supported	All Sides Fixed	61	0.65	0.66	0.66	0.666649	0.666649						
17		2-Side Supported	All Sides Pinned	62	0.66	0.666649	0.666649	0.666649	0.666649						
18		3-Side Supported	1st Yield Sym Span	71	0.65	0.65	0.66	0.666649	0.666649						
19		3-Side Supported	1st Yield Asym Span	72	0.65	0.66	0.66	0.666649	0.666649						
20		3-Side Supported	3 Sides Pinned	73	0.66	0.666649	0.666649	0.666649	0.666649						
21		4-Side Supported	All Sides Fixed	81	0.77	0.78	0.79	0.666649	0.666649						
22		4-Side Supported	All Sides Pinned	82	0.79	0.666649	0.666649	0.666649	0.666649						
23															
24															
25		Drop Down Lists													
26	1	User-Defined	Uniform Load				1	2	3	4	5	6	7	8	
27	2	Simply Supported	Point Load			1		Uniform Load	Uniform Load	Uniform Load	Uniform Load	All Sides Fixe	1st Yield Sym	All Sides Fixed	
28	3	Fixed-Fixed				2		Point Load	Point Load	Point Load	Point Load	All Sides Pinn	1st Yield Asym	All Sides Pinned	
29	4	Cantilever				3							3 Sides Pinne		
30	5	Propped Cantilever				4									
31	6	2-Side Supported				5									
32	7	3-Side Supported				6									
33	8	4-Side Supported				7									
34						8									
35	Lookup Values	2	1												
36															

Input | Results | Output | Load History | Lists | Resp. Crit. | LM Factors | Dyn Reac | PI Diagram

Figure 2-9 Load-Mass Factors Worksheet of NESDAS Software

2.7 PI DIAGRAM

The PI Diagram worksheet generates a Pressure-Impulse Diagram for the user-input SDOF parameters, when the user selects the “Generate PI Diagram” option from the command prompt on the Input Worksheet. This diagram generates a graph that shows the pressure and impulse values associated with a design load that will produce the maximum allowable displacement based on the response criteria input by the user. This design load is inherently assumed to be a triangular pulse load with an instantaneous rise to the peak pressure, and a linear decay.

Successful generation of a PI Diagram by the software is subject to all the restrictions previously mentioned for conducting an SDOF analysis (e.g., all mass and load mass factors must be greater than zero, etc.), and will result in the same error messages being displayed if the SDOF inputs are invalid. Additionally, the user must input values into the response criteria that result in a positive maximum allowable displacement; selection of negative response criteria that result in a negative or zero-value allowable displacement will generate an error message ("Response Criteria Invalid. Operation Aborted") and a cancellation of the operation.

Note that the algorithm for generating the PI diagram is a design aid, and not considered to be a sufficiently rigorous check for final analysis. E.g., the algorithm only considers inbound response, and does not consider potential rebound issues. The user is responsible for fully assessing the selected component for the intended design loads, using the full SDOF analysis calculation.

3.0 NESDAS ANALYSIS METHODOLOGY

This chapter describes the methodology used by the NESDAS software in computation of the dynamic response of an SDOF system. This includes discussion of the governing equations of motion utilized by the software, numerical methods used in its solving of the equations, interpretation of the user-input values, and major assumptions used by the software in its analysis.

Accurate calculation of the dynamic response of a general structural system using the software is dependent on the generation of appropriate parameters for input into the spreadsheet. However, this process must be manually performed by the user prior to use of the software to solve a specific problem. Generation of these parameters is thus considered to be outside of the specific scope of this software. The focus of this chapter is thus on the methodology used for dynamic analysis of the system once the appropriate SDOF parameters have been defined by the user. While the nature of SDOF modeling is briefly introduced and discussed, full details on this process are not provided. Such guidance is available in other design criteria (such as the UFC 3-340-02); the user is referred to such documents for further information.

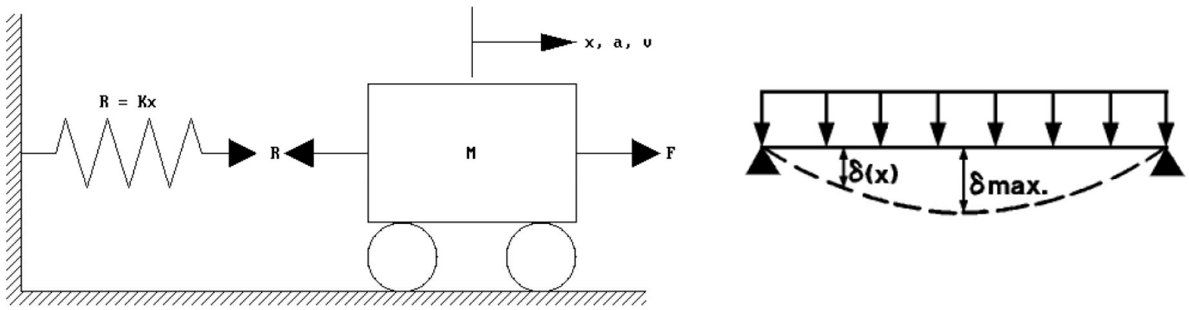
3.1 EQUATION OF MOTION FOR SDOF SYSTEM

The NESDAS software calculates the dynamic response of the considered SDOF system by solving the equation of motion for the system, presented below:

$$M * x'' + c * x' + R(x) = F$$

where M represents the mass of the system, c represents the damping constant, R(x) represents the structural resistance of the system to an applied load, F represents the applied load, and $x, x', and\ x''$ represent the displacement, velocity and acceleration of the system, respectively.

While the equation of motion described above is most representative of the response of a point mass acted on by a concentrated load (See Figure 3-1(a)), the same equation can also be used to describe the motion of a number of other structural systems, such as that of a beam deflecting under a distributed load (See Figure 3-1(b)), by simplifying the consideration of the element's response to a description of the element's deformation at a discrete point (typically the point of maximum displacement).



(a) (b)

Figure 3-1 (a) Idealized Single-Degree-of-Freedom Dynamically Responding System and (b) Flexural Element under Uniform Load to be Converted to Equivalent SDOF System

Use of the above equation of motion to predict the response of such continuous systems requires the calculation of a number of additional factors to represent the component as an equivalent SDOF system. This includes the calculation of an equivalent resistance function for the system (i.e. representing the system's stiffness and strength as a single function relating the deflection at the considered reference point to the total load resisted by the element). It also includes the calculation of dynamic load-mass factors for the system, which account for the inertial contribution of the system, taking into account the expected deflected shape of the system and pattern of applied loading. As noted previously, while the derivation of these parameters is critical to accurate calculation of the dynamic response of an equivalent SDOF system, this derivation must be done manually by the user prior to use of the NESDAS software, and will not be discussed further in this document. The user if referred to other design guidance for methods on the derivation of these factors.

For some SDOF systems (such as the response of a linearly-elastic system to an applied load defined by a singular function in time) the equation of motion can be solved exactly using methods of differential equations. However, typical SDOF systems analyzed for explosive safety within the DoD are often much more complex, involving resistance functions whose response is a non-linear function of displacement, and which are also path-dependent (i.e., such that the resistance at a given displacement can vary depending on the displacement history of the element prior to that point), in addition to other non-linearities (e.g., a change in the equivalent mass of the system due to a new load mass-factor resulting from yielding in the element). Typical practice thus consists of calculating the response of such SDOF systems through the use of numerical methods, approximating the response of the system by repeated solutions of the equation of motion at a series of discrete time steps. By reducing the size of these time steps to a sufficiently small interval, the error associated with this methodology is minimized, and the accuracy of the methodology is increased to the point of providing an appropriate prediction of the overall system response. Implementation of the numerical integration methodology used by the structure is detailed below.

3.2 NUMERICAL INTEGRATION OF EQUATION OF MOTION

The NESDAS software tool calculates the dynamic history of the considered SDOF system using the average acceleration method. This methodology works by predicting the acceleration at a given time-step under the applied load at that time-step and the expected structural response of the component to that load, based on the condition of the component at the previous time-step. The velocity and displacement at that time-step are then predicted based on the average of the acceleration of the previous and current time-step.

Due to potential non-linearities in the structural response, the nature of the structural response can vary between the actual behavior, and the behavior predicted based on the condition at the previous time-step, leading to errors in the produced solution. To account for this, the predictor-corrector method is utilized. In this method, the acceleration at each time-step is calculated twice. In the first, the acceleration at a given time-step (and subsequent velocity and displacement) are calculated based on the structural condition considering the velocity and displacement at the previous time-step. This "predicted" velocity and displacement are then used to re-calculate the predicted acceleration, based on the applied load and the expected structural response corresponding to the predicted velocity and displacement. This "corrected" acceleration prediction (and the velocity and displacement calculated based on this revised acceleration estimate) are then used as the final calculated values for that time-step. Those results are then used to predict the response at the next time-step, and the process is repeated through the full duration of the analysis. The equations used in this method are detailed in full below.

At the initial timestep (i.e. t=0ms or t0) the initial displacement, velocity and load are all known based on the input values provided by the user. Based on the prescribed initial displacement, the initial structural resistance is calculated (See Section 3.3) along with the assumed structural mass, damping and dynamic reaction based on the current phase of the system response (See Section 3.4 and 3.5). Based on these initial conditions, the acceleration at timestep t0 is then calculated based on the following equation:

$$a_{t0} = \frac{L_{t0} - R_{t0} - c_{t0} * \ v_{t0}}{m_{t0} + {}^{c_{t0}}/_{2} * \ dt}$$

where L_{t0} = the load at timestep t0, R_{t0} = the structural resistance at t0, c_{t0} = the damping coefficient at t0, v_{t0} = the velocity at t0, m_{t0} = the structural mass at t0, and dt = the timestep used in the analysis.

Based on this acceleration, the velocity at timestep t1 is calculated as $v_{t1} = \ v_{t0} + a_{t0} * dt$. Based on this velocity, the displacement at timestep t1 is calculated as $d_{t1} = \ d_{t0} + (v_{t0} + v_{t1})/2 * dt$. Again, the software calculates the system resistance, mass, damping and dynamic reactions associated with the displacement at that timestep. The acceleration at timestep t1 is then calculated, in a manner identical to that at timestep t0, save that the average velocity between the two timesteps is used, based on the previously calculated acceleration. I.e.:

$$a_{t1} = \frac{L_{t1} - R_{t1} - c_{t1} * \ (v_{t0} + a_{t0} * dt/2)}{m_{t1} + {}^{c_{t1}}/_{2} * \ dt}$$

For all other timesteps, the predictor-corrector method described previously is utilized. A predicted acceleration is calculated based on the system condition at the previous time-step and the load at the current timestep:

$$a_{pred} = \frac{L_{tn+1} - R_{tn} - c_{tn} * \ (v_{tn} + a_{tn} * dt/2)}{m_{tn} + {}^{c_{tn}}/_{2} * \ dt}$$

Based on this predicted acceleration, a predicted velocity and displacement are calculated in a manner similar to the previous calculations. I.e., $v_{pred} = v_{tn} + (a_{tn} + a_{pred})/2 * dt$ and $d_{pred} = d_{tn} + (v_{tn} + v_{pred})/2 * dt$. This predicted displacement is used to produce a revised estimate of the structural resistance R_{pred}, in accordance with the methods described in Section 3.3 below. This step is utilized to avoid compounding errors in the algorithm due to the nonlinearities in the resistance function for the system, as described previously.

Based on this predicted resistance, a corrected acceleration (a_{tn+1}) for the timestep is calculated, in a manner identical to that used for the predicted acceleration, with R_{pred} utilized in place of $R_{tn.}$ Then, a corrected velocity and displacement are calculated, again in a manner identical to the method used in the predictor step, with a_{tn+1} and v_{tn+1} used in place of a_{pred} and $v_{pred,}$ respectively. These corrected values for acceleration, velocity and displacement are taken as the final SDOF response values for that timestep, and also utilized to derive the final resistance value for the timestep, along with the assumed mass, damping coefficient, and dynamic reactions, based on the calculated phase of system response.

This predictor-corrector methodology is repeated for each time step throughout the remaining specified duration of the analysis. The calculated SDOF parameters are stored at each timestep, and exported to the Output worksheet, for analysis by the user in assessing the response of the system for compliance with the specified performance criteria.

3.3 MODELING OF STRUCTURAL RESISTANCE

The software computes the expected structural resistance at any given point in the system response based on a multi-linear resistance-stiffness function input by the user, considering both the current displacement of the element, and the load-displacement history of the system.

The resistance-function methodology used by the software considers elastic, elasto-plastic, plastic, and softening response of the system, including yielding of the system, along with a modeling of the hysteretic behavior of the element. The methodology models the response of the structure in a number of different ways, based on the current displacement of the element and the phase of its response. The assumptions used by the software in derivation of the resistance are detailed in the discussion below.

Note that for all discussion below, the resistance/displacement is discussed in absolute terms. I.e., a resistance "less than" a given value refers to a condition where the absolute value of the inbound or rebound resistance is less than the absolute value of the compared limit. "Loading" refers to an increase in the absolute value of the inbound or rebound resistance, while "unloading" refers to a decrease in the absolute value of the inbound or rebound resistance. The inbound and rebound response of the system is calculated using the same methodology, apart from potential differences in the user-input stiffness and resistance values for the two modes of response. Both modes are thus addressed simultaneously in the discussion below.

The algorithm first constructs an overall resistance-displacement function for the component, based on the limiting resistance and displacement values for each of the system's different phases of response. The limiting resistance values are taken directly from the user-specified values for the resistance function, defined in the Input Worksheet. For a stiffness-controlled analysis, the limiting displacement values are calculated based on the ratio of the resistance and the user-input stiffness values associated with that phase (i.e. X1 = R1/K1, X2-X1 = (R2-R1)/(K2), etc.) For a displacement-controlled analysis, the limiting displacement values are taken directly from the user-specified values in the Input Worksheet.

The algorithm also calculates a maximum elastic displacement for the system (d_{Emax}), based on the current maximum elastic resistance (R_{Emax}) divided by the elastic stiffness K_E (i.e., K1 for a stiffness-controlled analysis or R1/X1 for a displacement-controlled analysis), plus the "equilibrium displacement" for the element (d_{R0}) (i.e., the displacement at which the resistance of the element is equal to zero). This maximum elastic resistance is initially set equal to the user-input R1 value, while d_{Emax} is set equal to X1, and d_{R0} is set equal to zero. Note that the values for maximum elastic resistance, maximum elastic displacement, and equilibrium displacement may be different from the initial values at the initial timestep of the analysis, if the element is determined to have yielded under the initial displacement, requiring an update of the resistance-displacement function (See discussion below).

For any given timestep in the dynamic analysis, if the current/predicted displacement is determined to be less than the current d_{Emax}, the element is assumed to in the elastic phase of its response. Note that this includes any timestep where the absolute value of the displacement (relative to d_{R0}) is currently decreasing, even if the resistance of the component exceeds the initial elastic capacity of the system. In the elastic phase, the resistance of the element is calculated based on the elastic stiffness of the element, times the difference between the current displacement and the current d_{R0}. Load-mass factors (and according system mass), stiffness, damping, and dynamic reactions are all updated based on the values corresponding to this elastic phase of response, (See Section 3.4 and 3.5 below).

If the predicted displacement at a given time step (or under the initial displacement condition input by the user) is determined to exceed the d_{Emax}, the element is assumed to be in the inelastic phase of its response. The specific inelastic phase of the response is determined based on comparison between the current d_{Emax} and the user-input values for the resistance thresholds. Load-mass factors (and according system mass), stiffness, damping, and dynamic reactions are all updated based on the values corresponding to the specific phase of inelastic response.

For all inelastic phases of response, the system resistance at a given timestep is calculated through linear interpolation of the resistance-displacement function based on the current displacement, and the limiting resistance-displacement values for the considered phase of response. I.e., for a calculated displacement value between d_{Emax} and X1, $R_{new} = R_{Emax} + (d_{current} - d_{Emax})/(X2-d_{Emax})*(R2 - R_{Emax})$. Note that for the plastic phase of response, (i.e. anytime the current displacement exceeds the maximum defined displacement value), the system stiffness is assumed equal to zero, so the new resistance always remains equal to the current R_{Emax}, which is equal to the user-input R4 value.

After calculation of this system resistance, the software updates R_{Emax} to be equal to the new calculated system resistance, d_{Emax} is set equal to the current system displacement, and a new point of equilibrium displacement is established based on the current resistance, displacement and elastic stiffness, i.e.: $d_{R0} = d_{Emax} – (R_{Emax}/K_E)$.

Note that this update in equilibrium displacement results in an effective "shifting" of the resistance-displacement function corresponding to the response of the system in the opposite direction. I.e. if the system yields during its inbound response, the calculation methodology will predict the development of negative resistance at an earlier point than would be expected if the structure had not yielded under inbound loading.

This is considered consistent with the expected behavior of typical systems with positive stiffness. However, it is not necessarily representative of the expected behavior of systems that undergo structural softening, whose response is often controlled by other parameters. E.g., 2-way concrete slabs that undergo extreme deflections are assumed to experience structural softening due to the loss in capacity in one axis. The displacement values corresponding to this structural softening are assumed to be a function of the absolute support rotation of the system, and are not affected by the system's load-displacement history.

To preserve these values, an additional update to the displacement matrix is enacted by the software. This update is applied to the displacement matrix in the opposite direction (i.e., the rebound displacement matrix is updated if the system yields under inbound response). This update adjusts any displacement values associated with softening by the shift in the equilibrium displacement. Note that this adjustment applies to the displacement matrix, which is defined relative to the equilibrium displacement. The true effect of this adjustment is to preserve the absolute value of the displacement associated with structural softening. I.e., if the initial input values are such that the system begins to lose capacity at an absolute displacement of 2” from the initial condition, the system will still lose capacity at an absolute displacement of 2” despite any yielding that may have occurred in the opposite direction.

The different phases of potential structural resistance, and relevant parameters used by the software in assessment of its response, are noted in Figure 3-2, and described in Table 3-1 below.

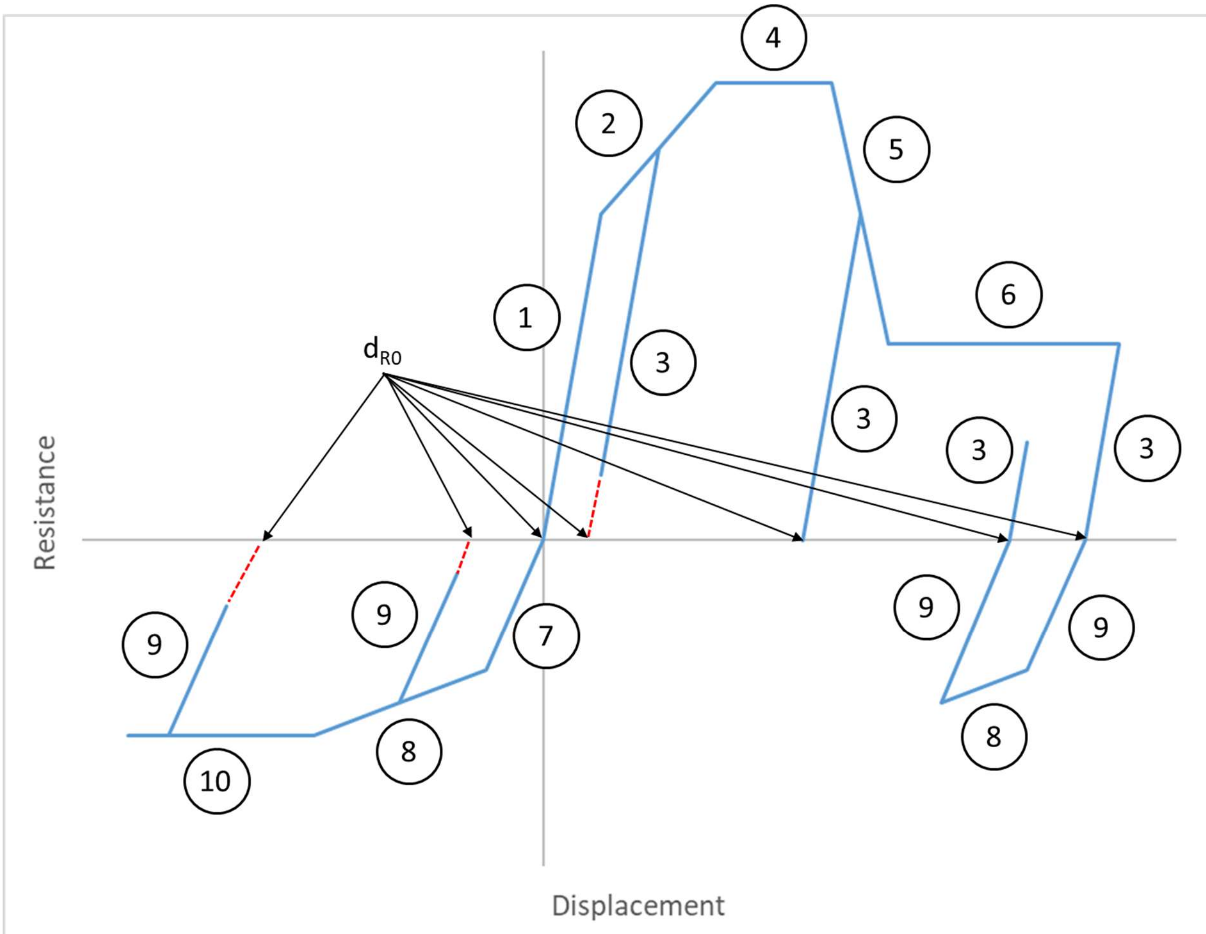


Figure 3-2 Regions of Response in Structural Resistance Function in NESDAS Software

Table 3-1 Structural Parameters used by NESDAS Software based on Region of Response

Region	Description	Stiffness	Load-Mass Factor	Dynamic Reaction Coeffs.	Max Elastic Resistance	Equilibrium Displacement
1	Inbound Loading/Unloading (Prior to Yield)	K1(Inb)	K_{LM}1(Inb)	Elastic	R1 (Inb)	Zero/ Unchanged
2	Inbound Loading (Elasto-Plastic Response)	K2(Inb)	K_{LM}2(Inb)	Elasto-Plastic	Current Resistance	$disp_{curr}$ - R_{curr}/K1(Inb)
3	Inbound Loading/Unloading (Post-Yield)	K1(Inb)	K_{LM}1(Inb)	Elastic	Unchanged	Unchanged
4	Inbound Loading (Plastic Phase)	0	K_{LM}3(Inb)	Plastic	Current Resistance	$disp_{curr}$ - R_{curr}/K1(Inb)
5	Inbound Loading (Softening Phase)	(X4-X3) / (R4-R3)	K_{LM}4(Inb)	Plastic	Current Resistance	$disp_{curr}$ - R_{curr}/K1(Inb)
6	Inbound Loading (Plastic Phase, Post-Softening)	0	K_{LM}5(Inb)	Plastic	Current Resistance	$disp_{curr}$ - R_{curr}/K1(Inb)
7	Rebound Loading/Unloading (Prior to Yield)	K1(Reb)	K_{LM}1(Reb)	Elastic	R1 (Reb)	Zero/ Unchanged
8	Rebound Loading (Elasto-Plastic Phase)	K2(Reb)	K_{LM}2(Reb)	Elasto-Plastic	Current Resistance	$disp_{curr}$ - R_{curr}/K1(Reb)
9	Rebound Loading/Unloading (Post-Yield)	K1(Reb)	K_{LM}1(Reb)	Elastic	Unchanged	Unchanged
10	Rebound Loading (Plastic Phase)	0	K_{LM}3(Reb)	Plastic	Current Resistance	$disp_{curr}$ - R_{curr}/K1(Reb)

3.4 ASSUMED STRUCTURAL MASS AND DAMPING

The assumed dynamic structural mass used in the calculation of the dynamic response of the considered SDOF system is based on the user-input value for the system mass and the applicable dynamic load-mass factor, based on the current phase of the system response, depending on the calculated resistance (See Section 3.3 above). E.g., if the structure is in the first elasto-plastic phase of response (between the elastic resistance and R2), the assumed dynamic mass is equal to mass*K_{lm}-2.

Recall that based on the previous displacement history of the element, the maximum elastic resistance of the element at a given time-step may be greater than R1. Thus, the assumed dynamic mass of the system may still be based on the elastic load-mass factor if the current resistance of the system is still below the current elastic resistance, even if that resistance is greater than R1 (or R2). See Table 3-1 above for the applicable load-mass factor utilized by the SDOF algorithm.

The structural damping applied to the system is based on the user-input values for critical damping ratio, as well as the structure's assumed stiffness and mass. The overall damping coefficient is calculated as: C = R_{cd}*2*K*M, where R_{cd} is the ratio of critical damping (specified by the user), K is the system stiffness and M is the system mass. Note that the system stiffness and mass vary during the dynamic response of the system, based on the current phase of the system response (e.g., elastic vs elasto-plastic). The system damping coefficient utilized in the SDOF algorithm thus varies throughout the system response. Note also that the system damping coefficient is inherently assumed to be zero during plastic response of the system, due to the zero system stiffness associated with that phase of response. The system damping coefficient is also assumed to be zero if the structure is currently in a phase of structural softening (i.e. has a negative stiffness). Finally, the system damping coefficient is also set equal to zero (vice the calculated value) during the elasto-plastic phase if the option to neglect elasto-plastic damping is selected by the user during system input (See Section 2.1.7).

3.5 DYNAMIC REACTION HISTORY

The dynamic reaction from the system is calculated based on the user-input values for dynamic reaction coefficients, applied load, structural resistance, and current phase of the system response. The dynamic reaction at a given timestep is calculated as: $R_{dyn}(t) = C_f*L(t) + C_r*R(t)$, where C_f is the dynamic reaction coefficient associated with force (specified in the Input Worksheet), L(t) is the applied load at the given timestep, C_f is the dynamic reaction coefficient associated with the structural resistance (specified in the Input Worksheet), and R(t) is the structural resistance at the given timestep. Note that the dynamic reaction coefficients are dependent on whether the system is currently assumed to be in an elastic, elasto-plastic, or plastic phase of its response (as discussed in Section 3.3 above). As with structural damping discussed above, elements that are in structural softening (i.e. have a negative stiffness) are assumed to be in the "plastic" phase, and use the corresponding dynamic reaction coefficients. See Table 3-1 above for the applicable dynamic reaction coefficients utilized by the SDOF algorithm.

This calculated dynamic reaction is expressed as an effective pressure value which is transmitted by the element to a supporting component. To determine the total dynamic reaction transmitted to a support by an element, this value should be multiplied by the span and loaded width of the considered element.

The software includes two functions for export of the calculated dynamic reactions for consideration of their effects on supporting elements, both accessed through the command prompt (See Section 2.1). The first of these is the "Export Dyn Reactions" command prompt, which exports the full pressure-time history associated with the dynamic reactions of the analyzed component (i.e., Columns "B" and "I" of the output spreadsheet) to a text file. The data in this text file can then be read into an alternate SDOF model (via the "Import Load History" command prompt) for assessing the effects of these reactions on an element supporting the analyzed component.

The second option is the "Export Comb. Load" command. This command produces a combined design pressure-time history, which considers both the effects of the dynamic reactions from a supported element on a supporting element, as well as the effects of the blast pressures that act directly on the surface of the supporting element (See Figure 3-3). The user defines the span of the supported element(s), as well as the width of the surface of the supporting element that is subjected to directly applied blast loads (which may differ from the width of the element if the supported element overlaps the edge of the supporting element), which dynamic reaction history to export, as well as whether the supported element is a cantilevered beam (See Figure 2-4 above). For 2-way elements, the input supported span should be based on the span of the 2-way element in the direction perpendicular to the supporting element.

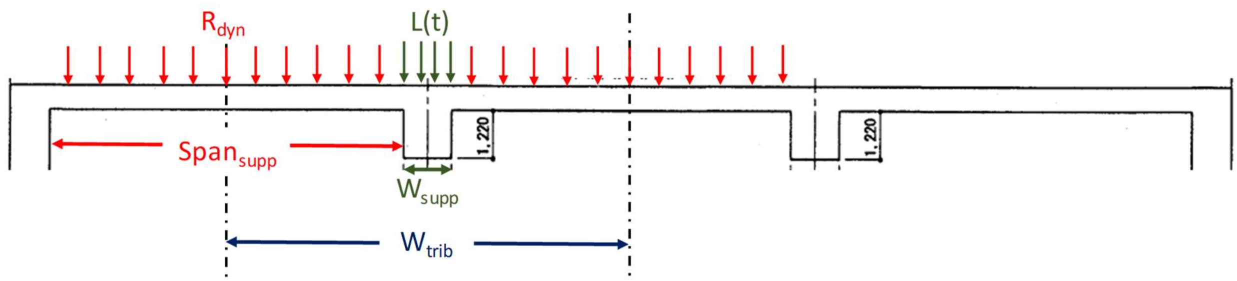


Figure 3-3 Combination of Directly-Applied Load on Surface of Concrete Beam and Dynamic Reactions from Supported Slabs

Based on these parameters, the software calculates an effective pressure that acts on the supporting element, based on the equation: $(R_{dyn}*Span_{supp} + L(t)*W_{supp})/W_{trib}$. This tributary width is assumed to be equal to the blast-exposed width of the supporting element plus half of the span of the supported element(s), or the full span of the supported element(s) if the supported element is a cantilever. This option can also be used to calculate the loading expected on a component supporting multiple elements (e.g. a concrete beam with slabs on either side), by simply inputting the combined sum of the spans of the two supported elements (assuming the supported elements have equivalent dynamic reaction histories). Note that the calculations based on the user-input dimensions are solely a function of the ratio of the values, and thus can be input in whichever unit the user prefers, but those units must be consistent between parameters.

Note that the tributary width assumed for the supporting element by the user in their determination of its SDOF parameters (i.e., mass, stiffness, resistance, etc.) must be consistent with the tributary width assumption used by the software for the calculated combined load history to be accurate. Note also that the applied load histories must be equivalent between all the considered elements for accurate calculation of their combined effects. If there are multiple supported elements of different structural configuration (such that their dynamic reaction histories are different), or if the loading on the supporting/supported elements vary (e.g., due to a non-uniform blast load over the surface), the software will not produce an accurate combined load-history. Combined load-histories in such scenarios must be manually calculated by the user.

4.0 VALIDATION STUDY

To assess the accuracy of the NESDAS software algorithm in predicting the response of an SDOF-system, a validation study was conducted comparing calculated results from the NESDAS software with response values reported in the UFC 3-340-02. Scenarios were run for all example problems in the UFC 3-340-02 Appendices 2 through 6 where applicable SDOF analyses could be conducted (i.e., where the UFC 3-340-02 example problems involved the dynamic analysis of a defined SDOF system under a specific pressure-time history.). Note that many of the UFC example problems define their SDOF parameters in alternate units (e.g., kips, ft, s). All such parameters were converted to psi, in, and ms for consistency with the unit assumptions built into the NESDAS software. The results of this validation study are summarized in Table 4-1 below. Full output files from the NESDAS software for the analyzed scenarios are provided in Appendix A

Table 4-1 Summary of Comparison between Reported Values for UFC 3-340-02 Example Problems and Results Calculated by NESDAS Software

	Xmax (in)			Tmax(ms)			Rmax (Rebound) (psi)			Tyield(ms)		
Problem	UFC	NESDAS	% Diff	UFC	NESDAS	% Diff	UFC	NESDAS	% Diff	UFC	NESDAS	% Diff
3A-5	3.377	3.39	0.27	77	77.2	0.3	-	-	-	20-30^	22.1	-
3A-6(a)*	3.55	3.60	1.32	0.98	1	2.0	-	-	-	0.26	0.27	3.1
3A-6(b)*	181	182	0.32	-	-	-	-	-	-	-	-	-
4A-1	0.274	0.28	1.45	9.7	9.8	1.0	-	-	-	-	-	-
4A-4	4.84	5.06	4.46	-	-	-	-	-	-	-	-	-
4A-6	1.29	1.27	-1.41	-	-	-	-	-	-	-	-	-
5A-1	2.69	2.80	4.01	-	-	-	-	-	-	9.6	8.6	-11.0
5A-3	1.17	1.09	-7.08	-	-	-	-1.75	-1.64	-6.5	-	-	-
5A-5(a)†	7.17	7.18	0.14	-	-	-	-1.09	-1.1	0.9	26	25.9	-0.4
5A-5(b)	-	-	-	28	28.7	2.5	-	-	-	-	-	-
5A-6	3.75	3.62	-3.53	-	-	-	-	-	-	-	-	-
5A-6 (Roof)	0.69	0.66	-4.44	-	-	-	-	-	-	-	-	-
5A-6 (Column)	0.8	0.75	-6.45	-	-	-	-	-	-	-	-	-
5A-7(a) (Plate)	0.713	0.71	-0.28	9.1	9.1	0.0	-	-	-	-	-	-
5A-7(a)	0.522	0.52	-1.16	-	-	-	-	-	-	-	-	-
5A-7(b)	1	1.05	5.07	-	-	-	-	-	-	1.8	1.7	-5.7
5A-8	2	2.02	0.80	-	-	-	-	-	-	-	-	-
6A-1	2.52	2.44	-3.23	-	-	-	-1.21	-1.21	0.0	-	-	-
6A-2	1.47	1.44	-1.85	-	-	-	-0.17	-0.16	-6.1	-	-	-

^ UFC Time Values Only reported in 10ms increments, accurate comparison with NESDAS results not possible
* System normalized assuming resistance of 1-psi, natural period of 1 ms
† Error in UFC-Reported Xmax due to Typo in Xe, Corrected for Validation Study

The NESDAS software showed good agreement with the reported values from the UFC 3-340-02, with an average absolute error of approximately 2.6% between the maximum displacements reported from the two sources, and half of the NESDAS-calculated values within 1.5% of the UFC 3-340-02 values. Agreement was also generally good between the two sources for the time to maximum displacement, maximum resistance in rebound, and time to yield displacement.

It must be noted that the UFC 3-340-02-reported values should not be interpreted as the “true” results for the SDOF system. Those values are (with the exception of problem 3A-5) derived from graphical interpolation of the various response charts provided in the UFC 3-340-02, and there is inherent coarseness in the resulting data. Note that for many of the example problems where there are larger relative differences between the two values, the magnitude of the error is driven largely by the number of significant digits in the UFC-reported values E.g., Example problem 5A-7(b), where the NESDAS-calculated time to yield is 1.7 ms, which differs by 0.1 ms from the UFC-reported value of 1.8 ms, which is the lowest possible difference between the two values given the precision of the UFC-reported number.

Accordingly, the differences between the values reported by the two sources should not be interpreted as indicative of an “error” in the values calculated by the NESDAS software, but merely inherent variability in answers generated by different methodologies. Nevertheless, the general high agreement between the two sources across a range of example problems and response parameters is considered to be indicative that the NESDAS software produces results that are consistent with the expected behavior of typical structural components which are assessed by SDOF analysis for protective construction, and is sufficiently accurate for use in the dynamic analysis of protective construction for explosive safety.

5.0 SUMMARY/CONCLUSIONS

This report has detailed the operation of the NAVFAC EXWC Single-Degree-of-Freedom Dynamic Analysis Spreadsheet software tool intended for the analysis of the dynamic response of single-degree-of-freedom systems subjected to blast loads, in support of protective construction analysis done for evaluation of structures for explosive safety in accordance with criteria established by the Department of Defense.

This report detailed the user interface of the NESDAS software, and provided guidance to the user in the use of the software, as well as limitations in its current functions. The report also provided a description of the analytical methods and assumptions that are utilized within the software tool. Finally, the report provided a validation study, comparing results obtained by the software with example problems provided in the UFC 3-340-02, which demonstrated that the software provides results consistent with existing DoD-approved methods for analysis of SDOF systems, and the software is considered to be sufficiently accurate for use in the dynamic analysis of protective construction for explosive safety.

6.0 REFERENCES

[1] Protective Design Center, "PDC-TR 06-02 Rev 3: User's Guide for the Single-Degree-of-Freedom Blast Effects Design Spreadsheet (SBEDS)," US Army Corps of Engineer, Decmber 2014.

[2] Department of Defense Explosive Safety Board, "Defense Explosives Safety Regulations 6055.09, Edition 1," DDESB, 2019.

[3] Unified Facilities Criteria, "UFC 3-340-02, Structures to Resist the Effects of Accidental Explosions, With Change 2," Department of Defense Explosives Safety Board, Alexandria, VA, 1 Sept 2014.

[4] NOSSA, *NOSSA Instruction 8020.22A, Quantity-Distance, Risk-Based, and Hybrid Safety Submission Requirements, NOSSAINST 8020.22A,* Indian Head, MD: Naval Ordnance Safety and Security Activity, 8 Feb 2023.

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APPENDIX A

VALIDATION STUDY - NESDAS OUTPUT FILES

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NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 3A-5

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	1000000
100	0
100	0
100	0
100	0
100	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	208000000	208000000	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	1	1	
KLM2	1	1	
KLM3	1	1	
KLM4	1	1	
KLM5	1	1	
Stiffness			
K1	821700	821700	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	750000	750000	psi
R2	750000	750000	psi
R3	750000	750000	psi
R4	750000	750000	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.913	0.913	in
Yield Line Distance		0	in

Analysis Parameters		
Natural period	99.97	ms
Time step	0.10	ms
Duration	299.93	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

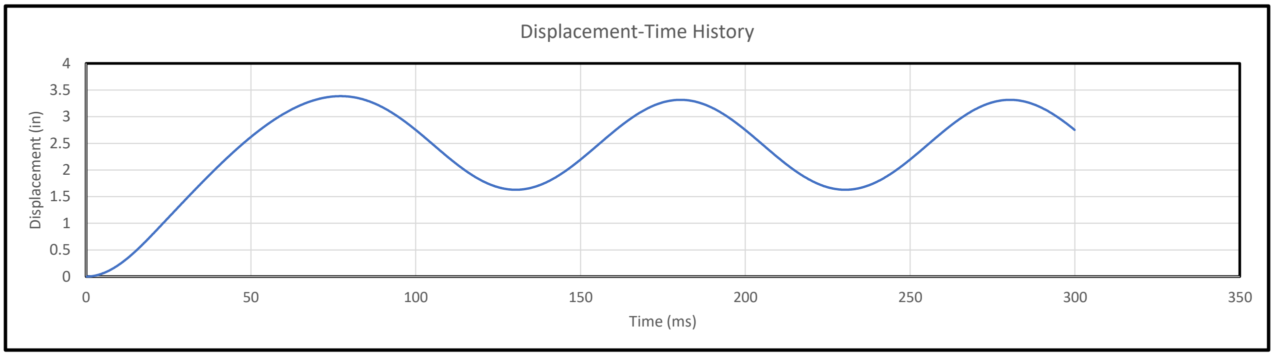
Results Summary

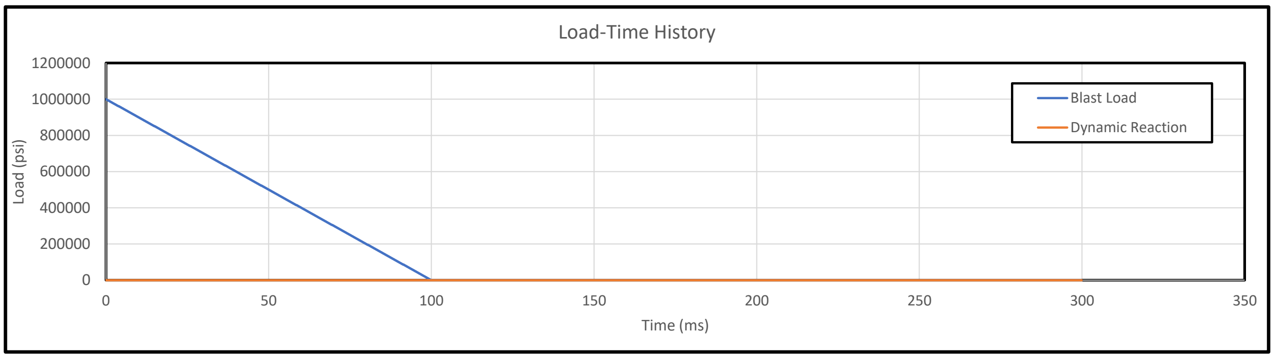
Max. Defl. (in)	3.386	Max Supp. Rot.	0.00	deg
Time to Max. Resp. (ms)	77.200	Max Ductility	3.71	
Time to Yield Defl. (ms)	22.100			
		Max Inbound Resist	750000	psi
		Max Rebound Resist	-693222	psi

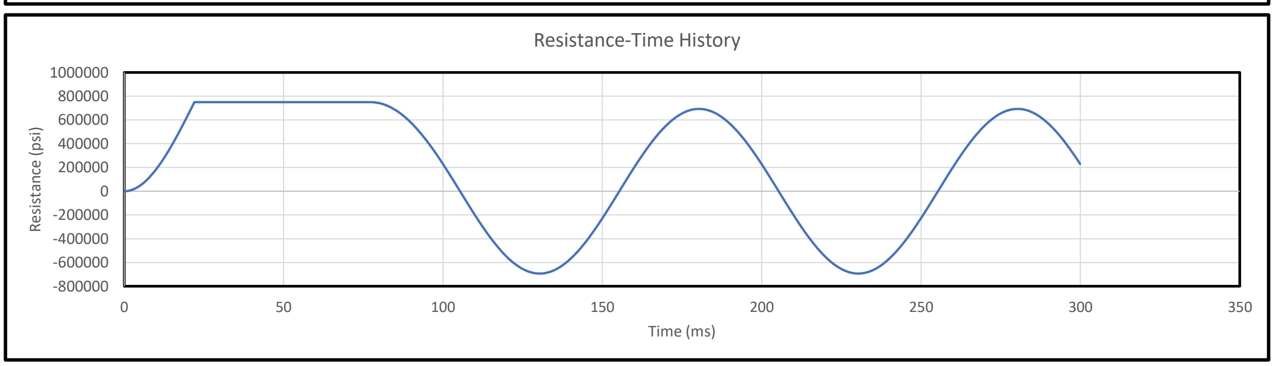
No Criteria Specified

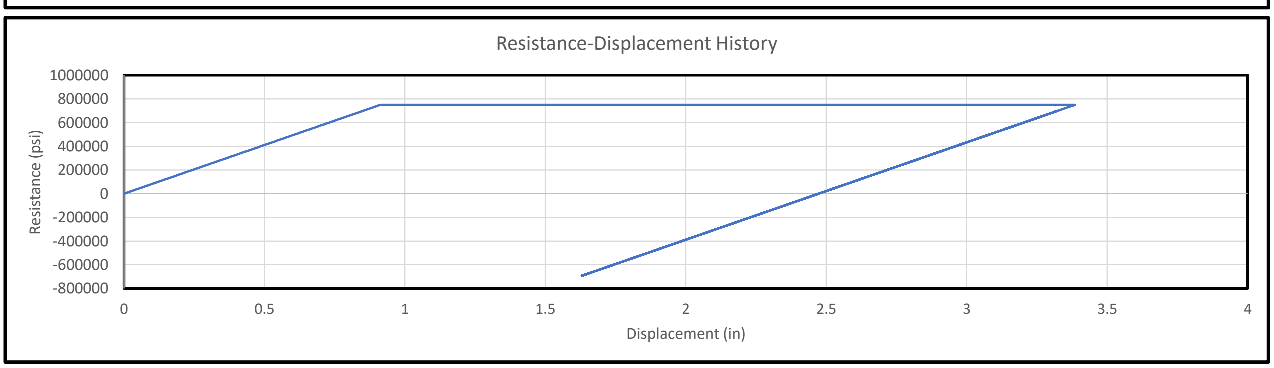
Project/Location	UFC 3-340-02	Building	Validation Study	Component	3A-5
		Analyzed By	SMD	Date	8/4/2023

Results Summary					
Max. Defl. (in)	3.386	Max Supp. Rot.	0.00	deg	No Criteria Specified
Time to Max. Resp. (ms)	77.2	Max Ductility	3.71		
Time to Yield Defl. (ms)	22.1				
		Max Inbound Resist	750000.00	psi	
		Max Rebound Resist	-693221.66	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location	UFC 3-340-02	Building	Validation Study	Component	3A-6(a)
Command Prompt:		Analyzed By	SMD	Date	8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	1
1.085	0.6383
50	0
50	0
50	0
50	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	0.02534	0.02534	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	1	1	
KLM2	1	1	
KLM3	1	1	
KLM4	1	1	
KLM5	1	1	
Stiffness			
K1	1	1	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	1	1	psi
R2	1	1	psi
R3	1	1	psi
R4	1	1	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	1.000	1.000	in
Yield Line Distance		0	in

Analysis Parameters		
Natural period	1.00	ms
Time step	0.03	ms
Duration	52.00	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

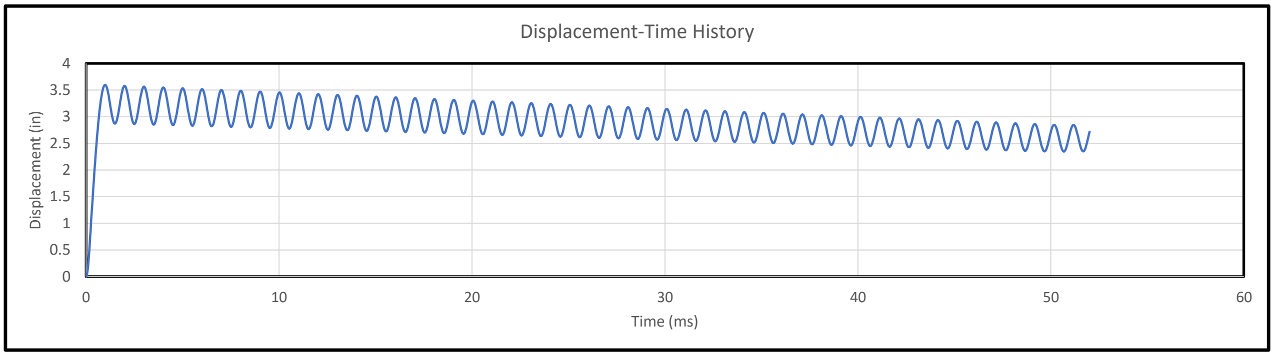
Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

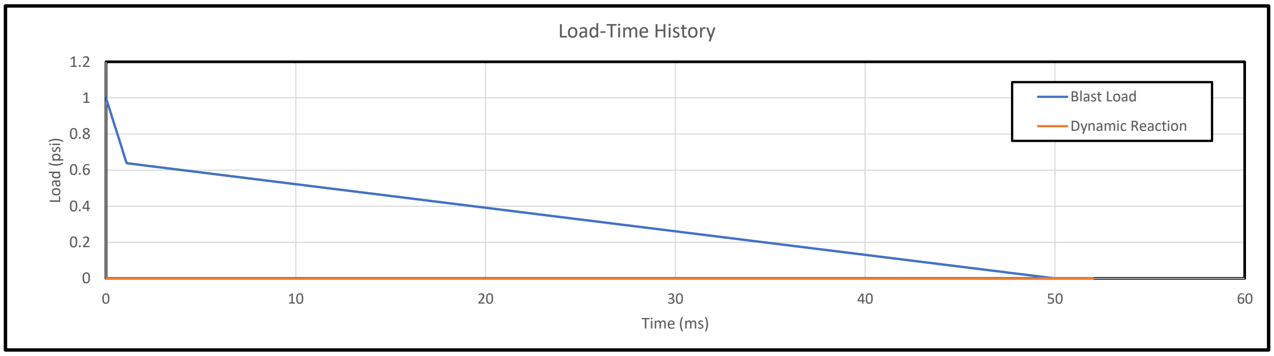
Results Summary

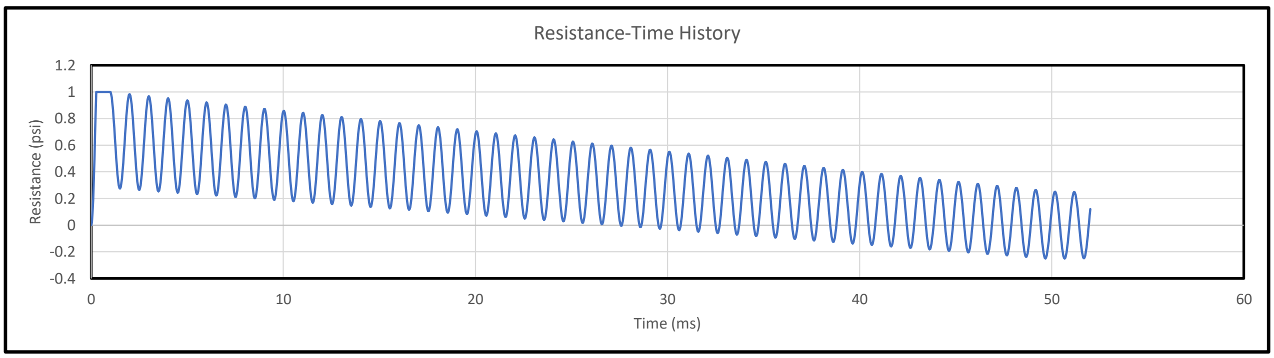
Max. Defl. (in)	3.597	Max Supp. Rot.	0.00	deg	No Criteria Specified
Time to Max. Resp. (ms)	1.000	Max Ductility	3.60		
Time to Yield Defl. (ms)	0.267				
		Max Inbound Resist	1	psi	
		Max Rebound Resist	0	psi	

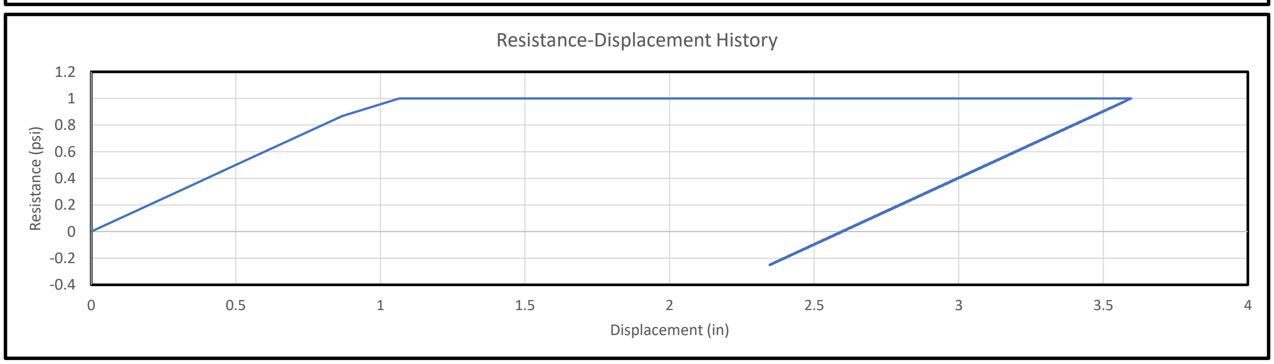
Project/Location	UFC 3-340-02	Building	Validation Study	Component	3A-6(a)
		Analyzed By	SMD	Date	8/4/2023

Results Summary					
Max. Defl. (in)	3.597	Max Supp. Rot.	0.00	deg	No Criteria Specified
Time to Max. Resp. (ms)	1.000191533	Max Ductility	3.60		
Time to Yield Defl. (ms)	0.266717742				
		Max Inbound Resist	1.00	psi	
		Max Rebound Resist	-0.25	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 3A-6(b)

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	32
0.094284	1.829
2	0
2	0
2	0
2	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	0.02534	0.02534	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	1	1	
KLM2	1	1	
KLM3	1	1	
KLM4	1	1	
KLM5	1	1	
Stiffness			
K1	1	1	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	1	1	psi
R2	1	1	psi
R3	1	1	psi
R4	1	1	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	1.000	1.000	in
Yield Line Distance		0	in

Analysis Parameters		
Natural period	1.00	ms
Time step	0.02	ms
Duration	4.00	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

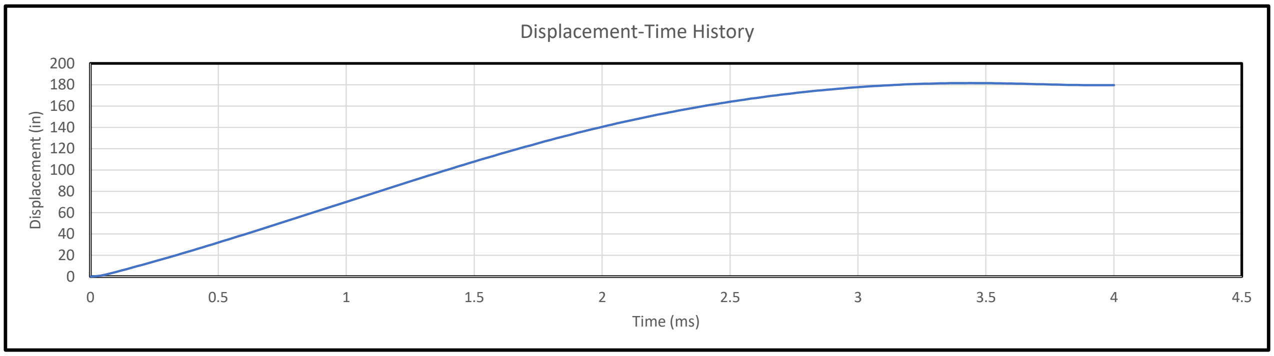
Results Summary				
Max. Defl. (in)	181.573	Max Supp. Rot.	0.00	deg
Time to Max. Resp. (ms)	3.441	Max Ductility	181.57	
Time to Yield Defl. (ms)	0.060			
		Max Inbound Resist	1	psi
		Max Rebound Resist	-1	psi

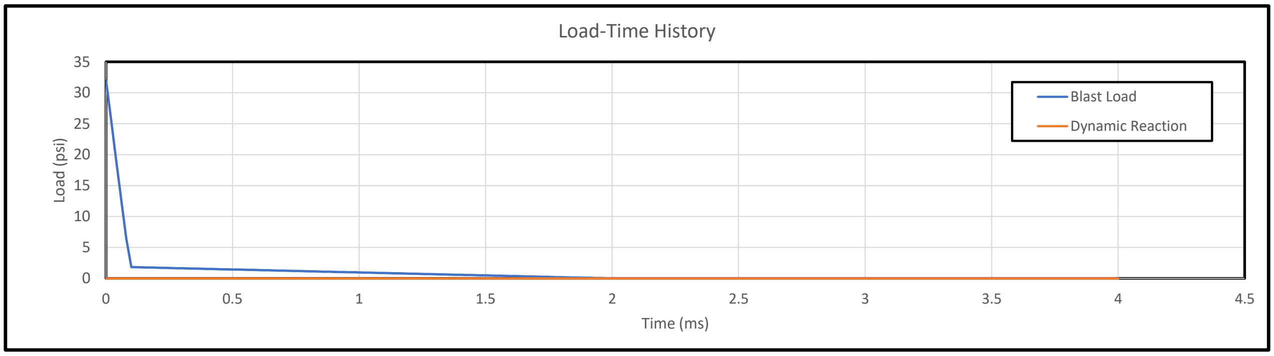
No Criteria Specified

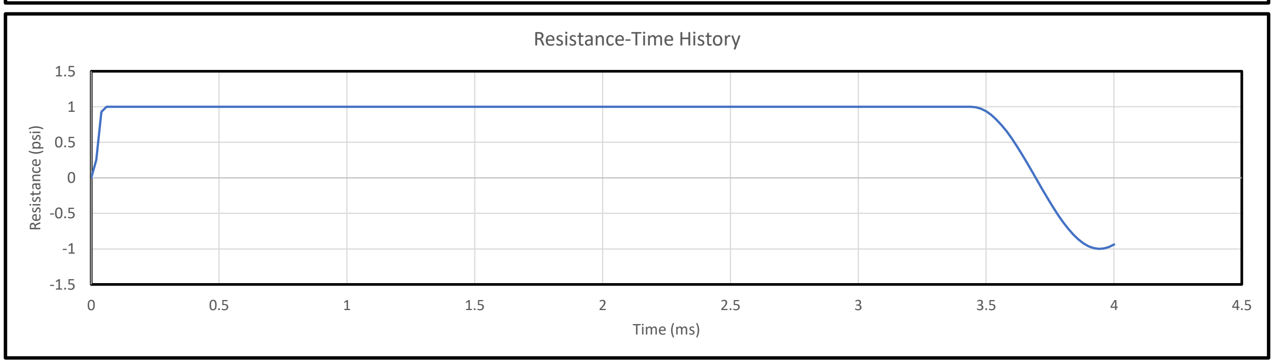
Project/Location	UFC 3-340-02	Building	Validation Study	Component	3A-6(b)
		Analyzed By	SMD	Date	8/4/2023

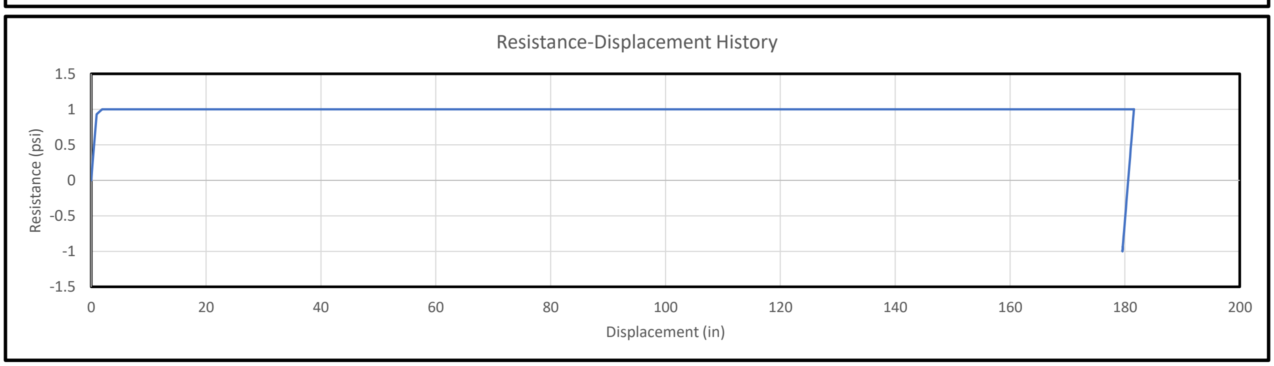
Results Summary

Max. Defl. (in)	181.573	Max Supp. Rot.	0.00	deg	No Criteria Specified
Time to Max. Resp. (ms)	3.440658873	Max Ductility	181.57		
Time to Yield Defl. (ms)	0.060011492				
		Max Inbound Resist	1.00	psi	
		Max Rebound Resist	-1.00	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 4A-1

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	35
10.5	0
10.5	0
10.5	0
10.5	0
10.5	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	2700	2700	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.6	0.6	
KLM2	0.6	0.6	
KLM3	0.6	0.6	
KLM4	0.6	0.6	
KLM5	0.6	0.6	
Stiffness			
K1	246.2	246.2	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	24.13	24.13	psi
R2	24.13	24.13	psi
R3	24.13	24.13	psi
R4	24.13	24.13	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.098	0.098	in
Yield Line Distance		0	in

Analysis Parameters		
Natural period	16.12	ms
Time step	0.10	ms
Duration	42.73	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

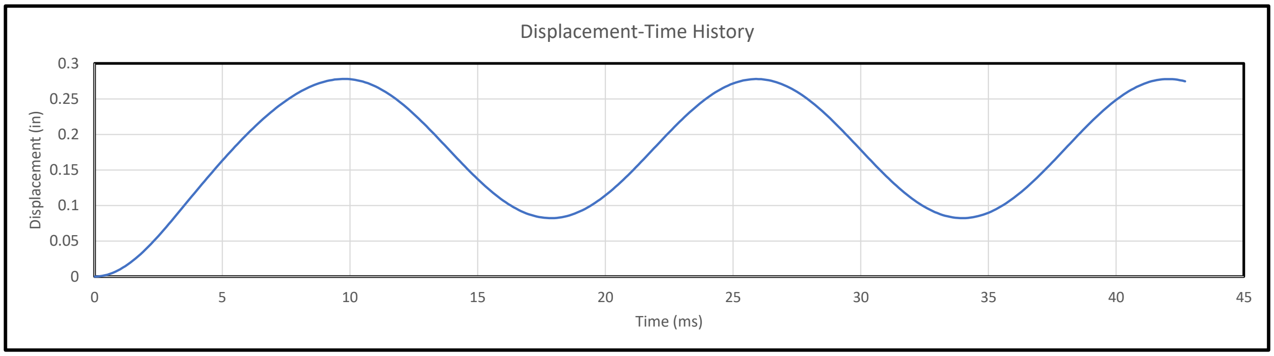
Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

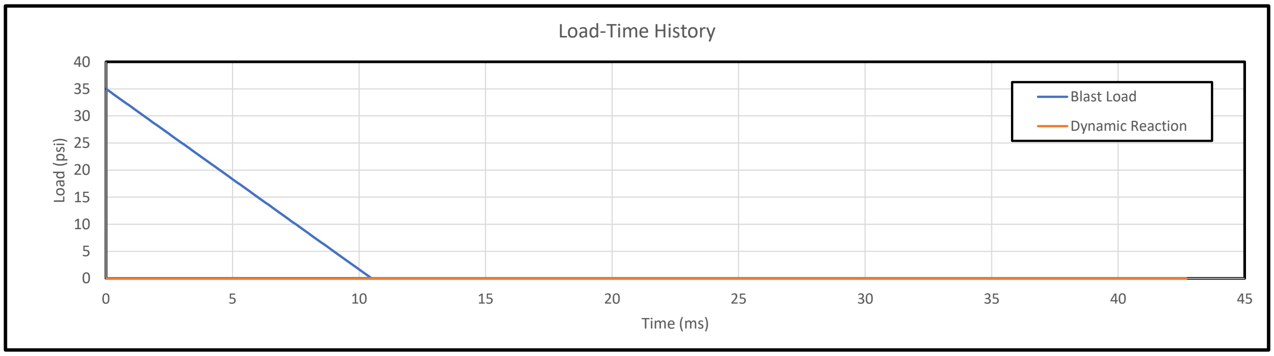
Results Summary

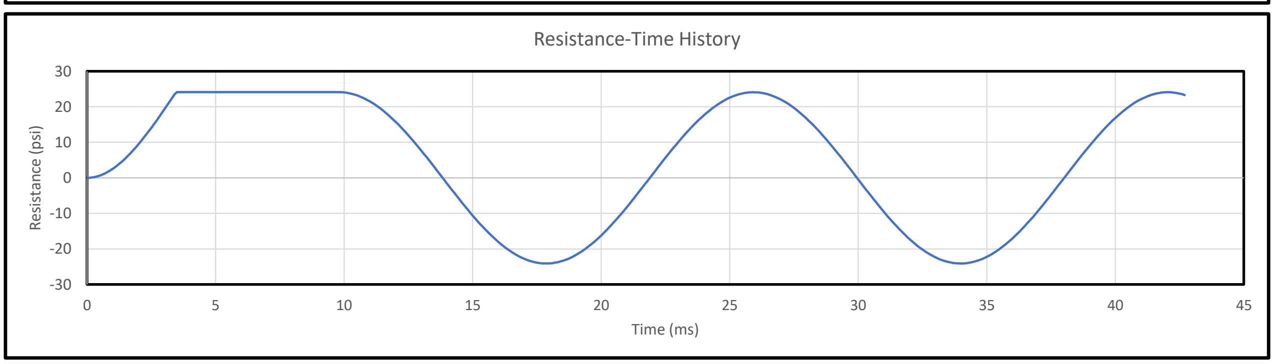
Max. Defl. (in)	0.278	Max Supp. Rot.	0.00	deg	No Criteria Specified
Time to Max. Resp. (ms)	9.800	Max Ductility	2.84		
Time to Yield Defl. (ms)	3.500				
		Max Inbound Resist	24.13	psi	
		Max Rebound Resist	-24.10	psi	

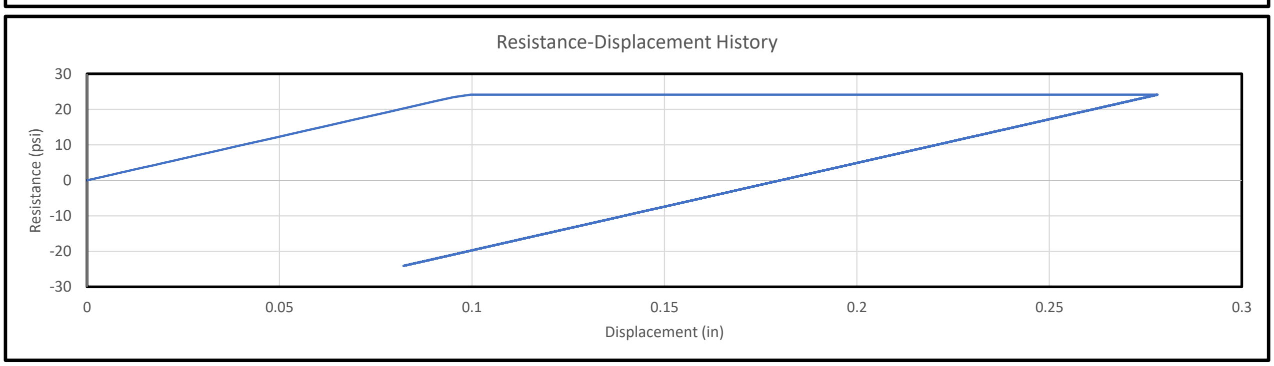
Project/Location	UFC 3-340-02	Building	Validation Study	Component	4A-1
		Analyzed By	SMD	Date	8/4/2023

Results Summary					
Max. Defl. (in)	0.278	Max Supp. Rot.	0.00	deg	No Criteria Specified
Time to Max. Resp. (ms)	9.8	Max Ductility	2.84		
Time to Yield Defl. (ms)	3.5				
		Max Inbound Resist	24.13	psi	
		Max Rebound Resist	-24.10	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location	UFC 3-340-02	Building	Validation Study	Component	4A-4
Command Prompt:		Analyzed By	SMD	Date	8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	1485
1.2	0
1.2	0
1.2	0
1.2	0
1.2	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	4072	4072	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.6	0.6	
KLM2	0.6	0.6	
KLM3	0.6	0.6	
KLM4	0.6	0.6	
KLM5	0.6	0.6	
Stiffness			
K1	36.7	36.7	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	35.53	35.53	psi
R2	35.53	35.53	psi
R3	35.53	35.53	psi
R4	35.53	35.53	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.968	0.968	in
Yield Line Distance		144	in

Analysis Parameters		
Natural period	51.27	ms
Time step	0.04	ms
Duration	103.73	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

Results Summary

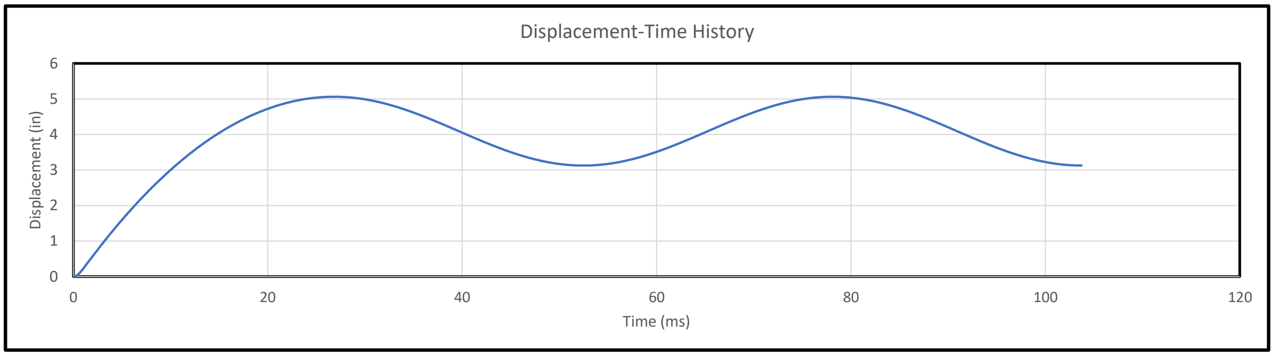
Max. Defl. (in)	5.061	Max Supp. Rot.	2.01	deg
Time to Max. Resp. (ms)	26.840	Max Ductility	5.23	
Time to Yield Defl. (ms)	3.120			
		Max Inbound Resist	35.53	psi
		Max Rebound Resist	-35.53	psi

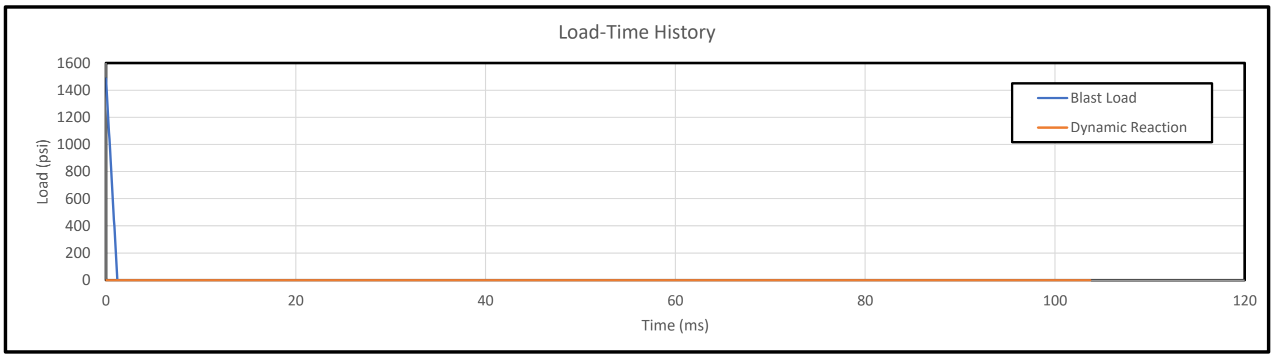
No Criteria Specified

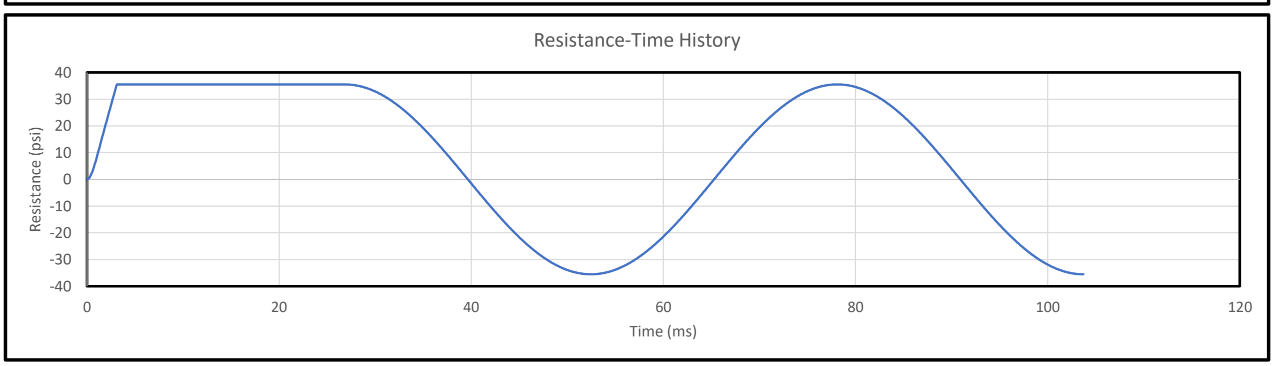
Project/Location	UFC 3-340-02	Building	Validation Study	Component	4A-4
		Analyzed By	SMD	Date	8/4/2023

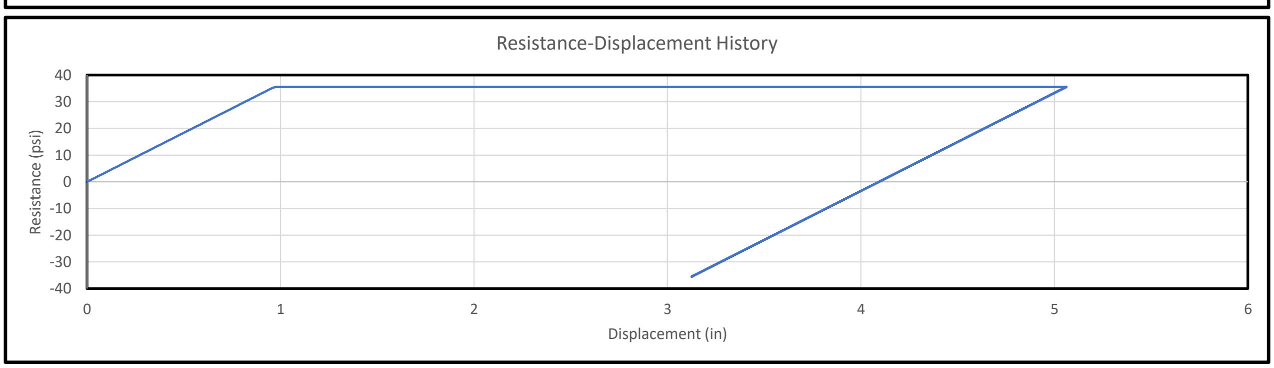
Results Summary

Max. Defl. (in)	5.061	Max Supp. Rot.	2.01	deg	No Criteria Specified
Time to Max. Resp. (ms)	26.84	Max Ductility	5.23		
Time to Yield Defl. (ms)	3.12				
		Max Inbound Resist	35.53	psi	
		Max Rebound Resist	-35.53	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 4A-6

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	1598.4
60.7	0
60.7	0
60.7	0
60.7	0
60.7	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	194638.5	194638.5	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	8629.7	8629.7	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	1236.79	1236.79	psi
R2	1236.79	1236.79	psi
R3	1236.79	1236.79	psi
R4	1236.79	1236.79	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.143	0.143	in
Yield Line Distance		120	in

Analysis Parameters		
Natural period	25.32	ms
Time step	0.10	ms
Duration	111.34	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

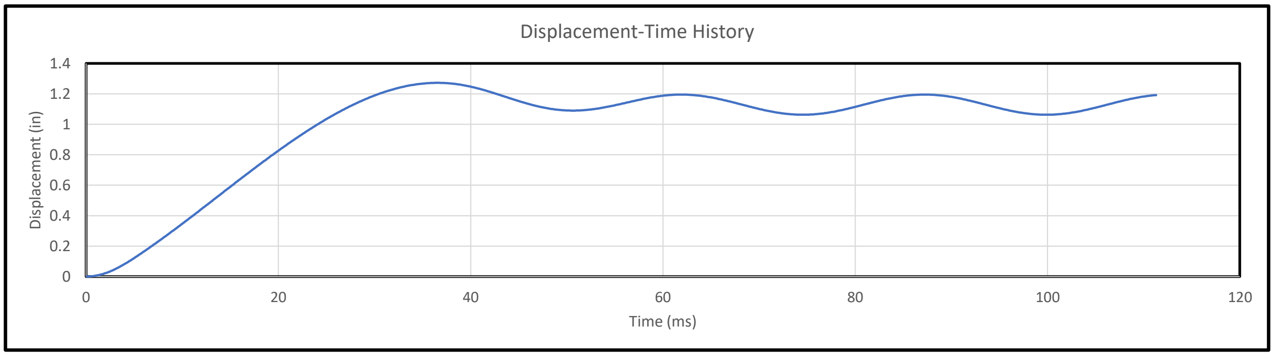
Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

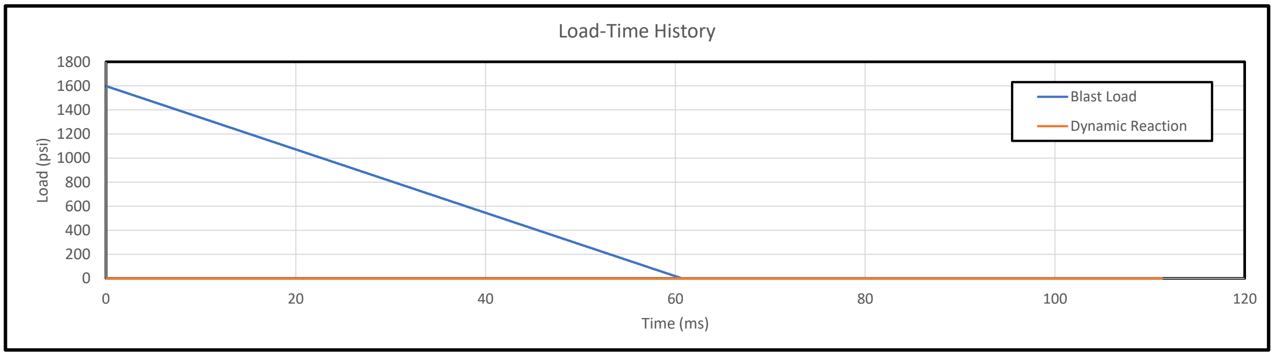
Results Summary

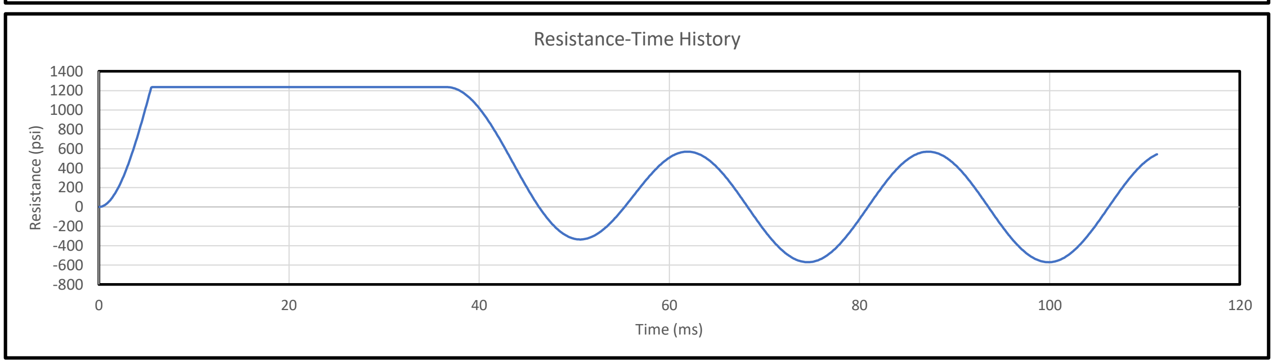
Max. Defl. (in)	1.272	Max Supp. Rot.	0.61	deg	No Criteria Specified
Time to Max. Resp. (ms)	36.600	Max Ductility	8.88		
Time to Yield Defl. (ms)	5.600				
		Max Inbound Resist	1236.79	psi	
		Max Rebound Resist	-570.49	psi	

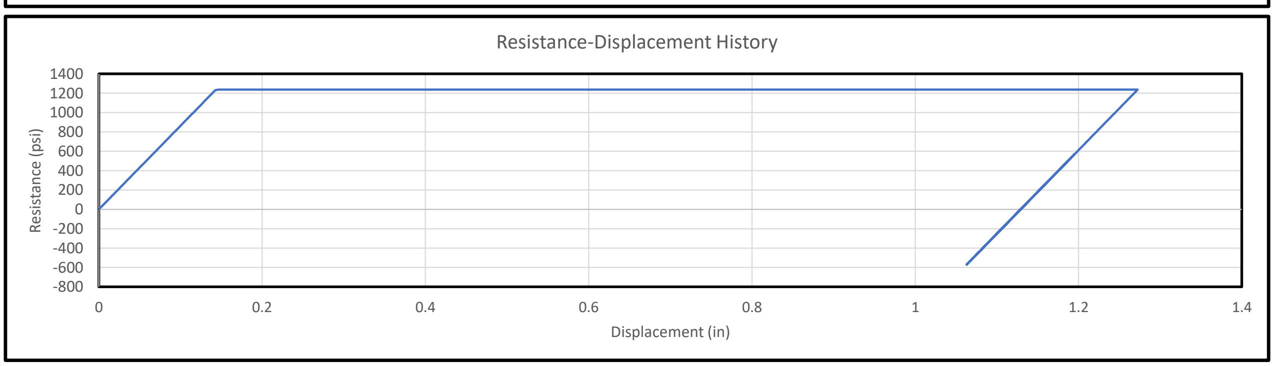
Project/Location	UFC 3-340-02	Building	Validation Study	Component	4A-6
		Analyzed By	SMD	Date	8/4/2023

Results Summary						
Max. Defl. (in)	1.272	Max Supp. Rot.	0.61	deg	No Criteria Specified
Time to Max. Resp. (ms)	36.6	Max Ductility	8.88		
Time to Yield Defl. (ms)	5.6				
		Max Inbound Resist	1236.79	psi	
		Max Rebound Resist	-570.49	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-1
Command Prompt:		Analyzed By	SMD	Date	8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	6.5
40	0
40	0
40	0
40	0
40	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	190.102	190.102	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	5.023	5.023	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	6.418	6.418	psi
R2	6.418	6.418	psi
R3	6.418	6.418	psi
R4	6.418	6.418	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	1.278	1.278	in
Yield Line Distance		102	in

Analysis Parameters		
Natural period	32.80	ms
Time step	0.10	ms
Duration	105.60	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

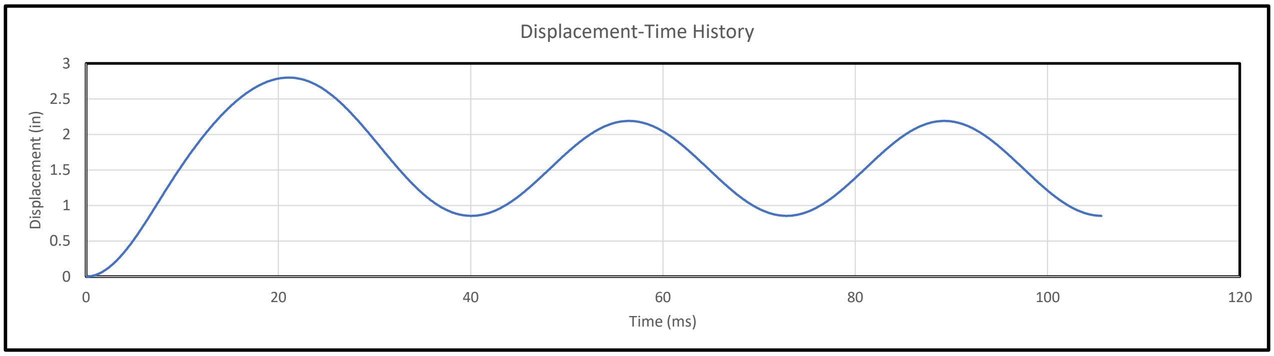
Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

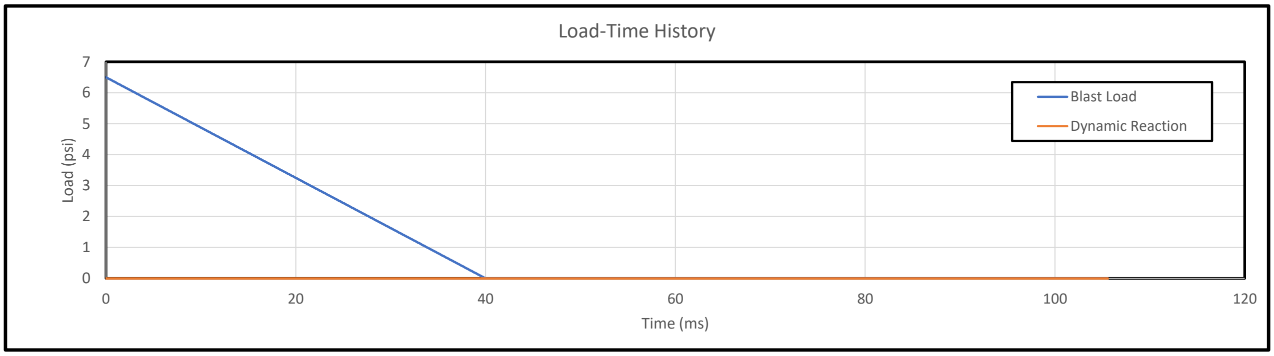
Results Summary				
Max. Defl. (in)	2.800	Max Supp. Rot.	1.57	deg
Time to Max. Resp. (ms)	21.100	Max Ductility	2.19	
Time to Yield Defl. (ms)	8.600			
		Max Inbound Resist	6.42	psi
		Max Rebound Resist	-3.35	psi

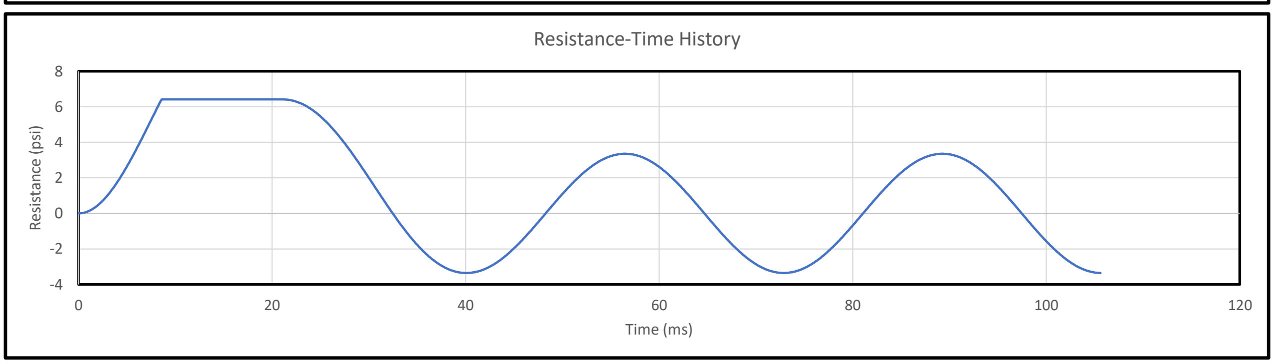
No Criteria Specified

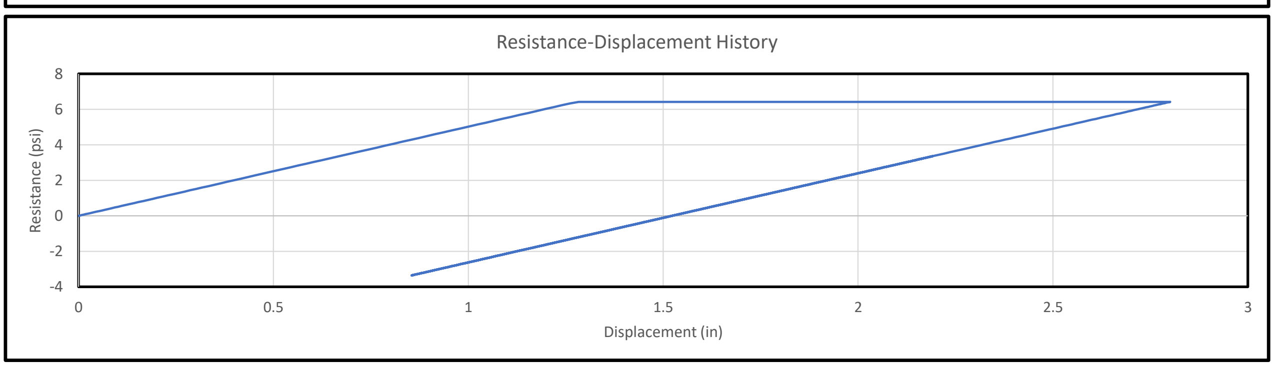
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-1
		Analyzed By	SMD	Date	8/4/2023

Results Summary					
Max. Defl. (in)	2.800	Max Supp. Rot.	1.57	deg	No Criteria Specified
Time to Max. Resp. (ms)	21.1	Max Ductility	2.19		
Time to Yield Defl. (ms)	8.6				
		Max Inbound Resist	6.42	psi	
		Max Rebound Resist	-3.35	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 5A-3

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	5
40	0
40	0
40	0
40	0
40	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	52.161	52.161	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.74	0.74	
KLM2	0.74	0.74	
KLM3	0.74	0.74	
KLM4	0.74	0.74	
KLM5	0.74	0.74	
Stiffness			
K1	15.98	15.98	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	5.319	5.319	psi
R2	5.319	5.319	psi
R3	5.319	5.319	psi
R4	5.319	5.319	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.333	0.333	in
Yield Line Distance		27	in

Analysis Parameters		
Natural period	9.77	ms
Time step	0.10	ms
Duration	59.53	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

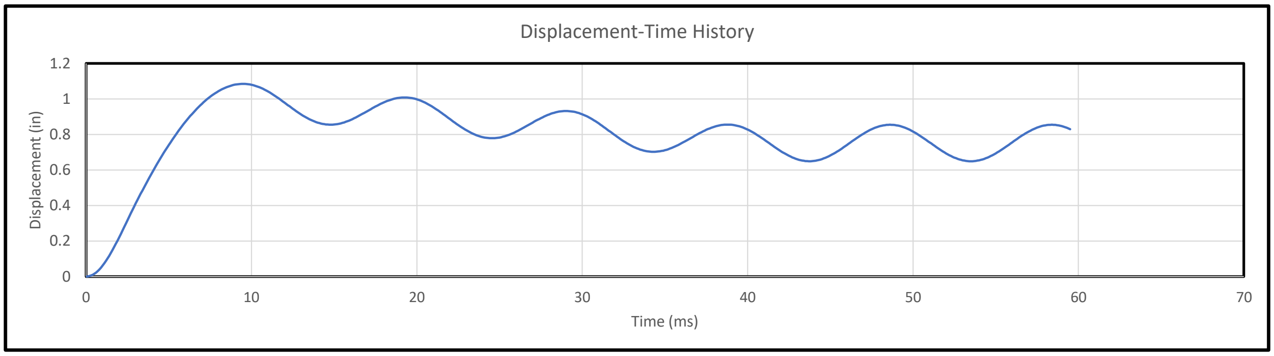
Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

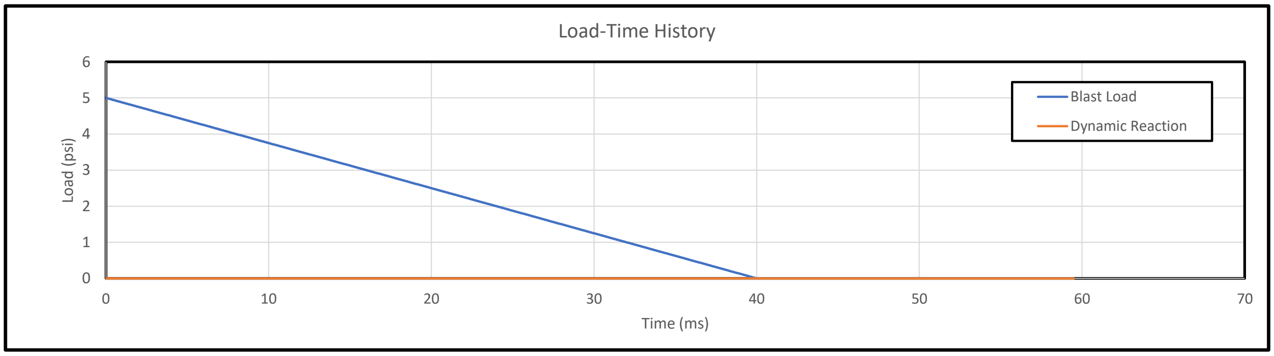
Results Summary

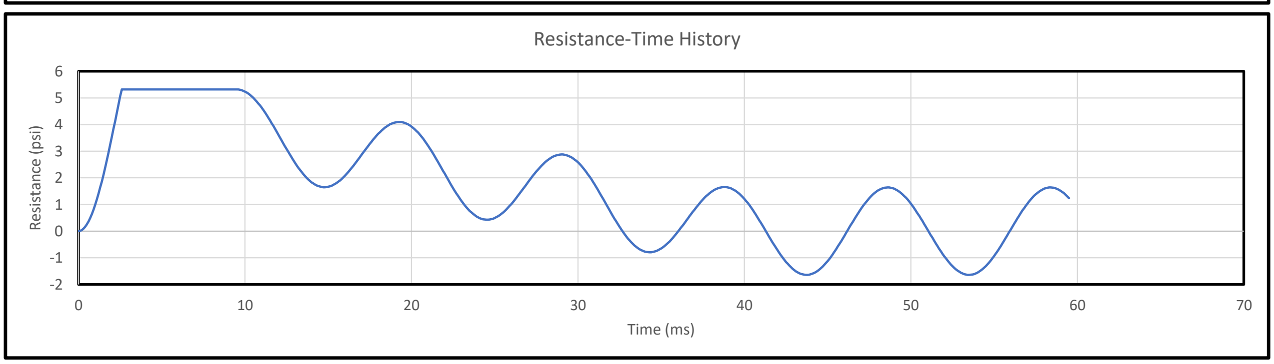
Max. Defl. (in)	1.085	Max Supp. Rot.	2.30	deg	No Criteria Specified
Time to Max. Resp. (ms)	9.500	Max Ductility	3.26		
Time to Yield Defl. (ms)	2.600				
		Max Inbound Resist	5.32	psi	
		Max Rebound Resist	-1.64	psi	

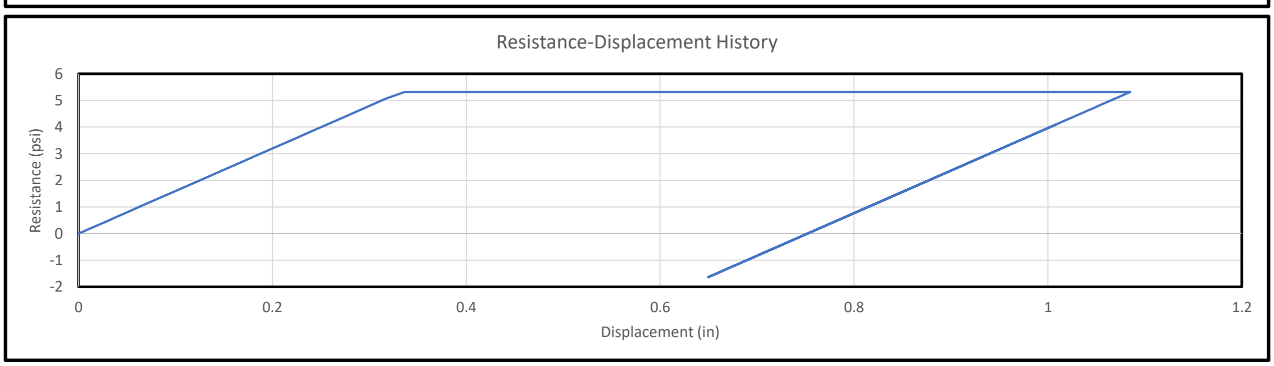
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-3
		Analyzed By	SMD	Date	8/4/2023

Results Summary						
Max. Defl. (in)	1.085	Max Supp. Rot.	2.30	deg		No Criteria Specified
Time to Max. Resp. (ms)	9.5	Max Ductility	3.26			
Time to Yield Defl. (ms)	2.6					
		Max Inbound Resist	5.32	psi		
		Max Rebound Resist	-1.64	psi		









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 5A-5(a)

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	2
40	0
40	0
40	0
40	0
40	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	143.849	143.849	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	0.283	0.283	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	1.205	1.0959	psi
R2	1.205	1.0959	psi
R3	1.205	1.0959	psi
R4	1.205	1.0959	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	4.258	3.872	in
Yield Line Distance		300	in

Analysis Parameters		
Natural period	120.20	ms
Time step	0.10	ms
Duration	280.40	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

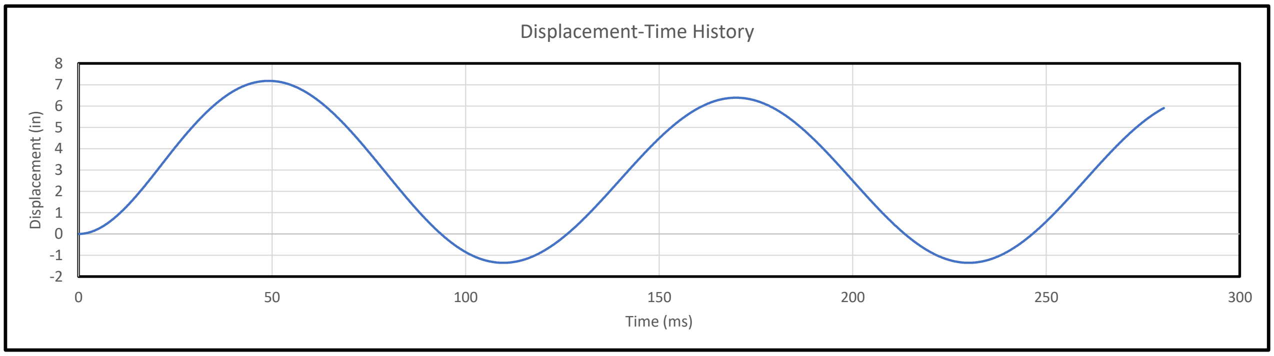
Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

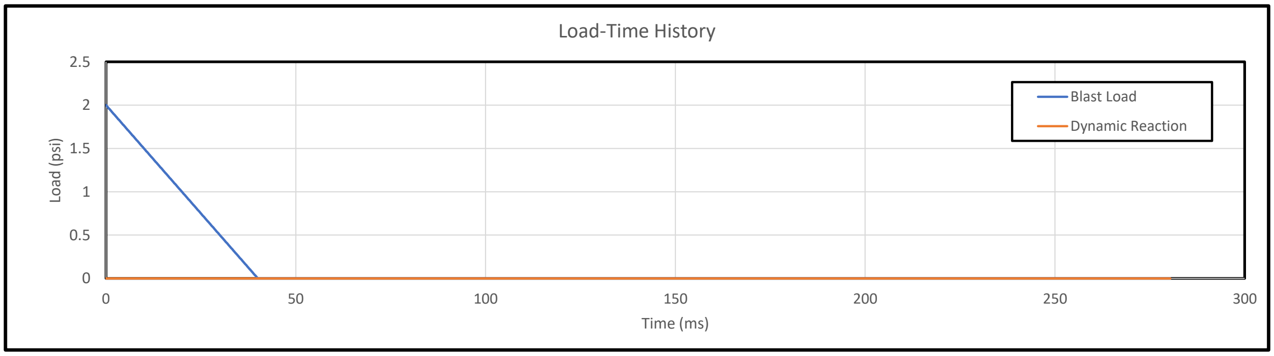
Results Summary

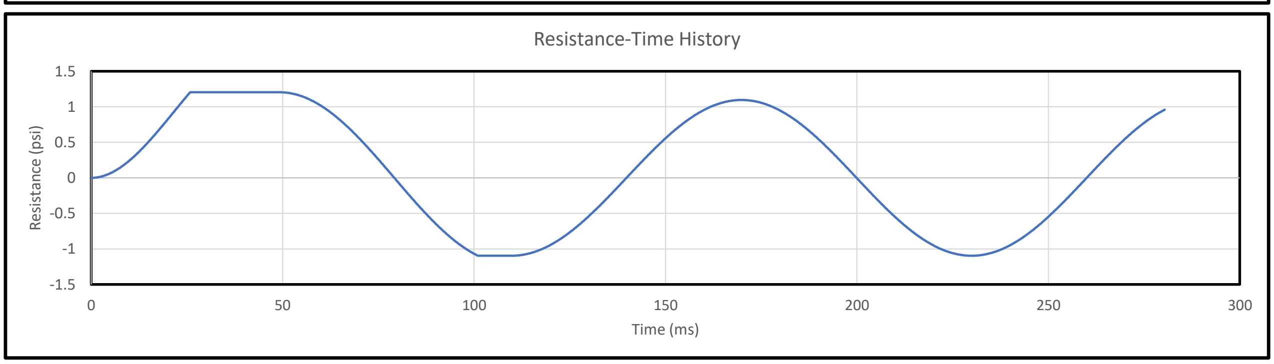
Max. Defl. (in)	7.180	Max Supp. Rot.	1.37	deg	No Criteria Specified
Time to Max. Resp. (ms)	49.100	Max Ductility	1.69		
Time to Yield Defl. (ms)	25.900				
		Max Inbound Resist	1.21	psi	
		Max Rebound Resist	-1.10	psi	

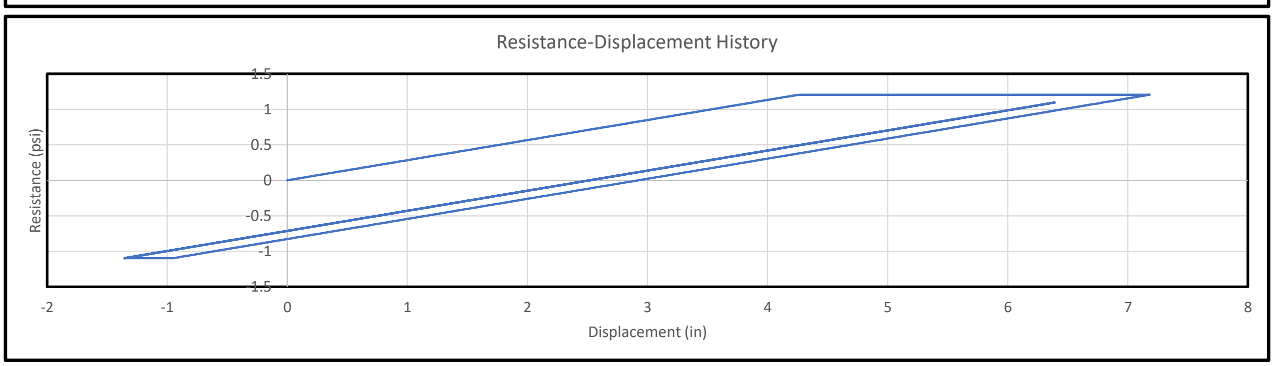
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-5(a)
		Analyzed By	SMD	Date	8/4/2023

Results Summary						
Max. Defl. (in)	7.180	Max Supp. Rot.	1.37	deg		No Criteria Specified
Time to Max. Resp. (ms)	49.1	Max Ductility	1.69			
Time to Yield Defl. (ms)	25.9					
		Max Inbound Resist	1.21	psi		
		Max Rebound Resist	-1.10	psi		









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-5(b)
Command Prompt:		Analyzed By	SMD	Date	8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	1
25	0
25	0
25	0
25	0
25	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	122.97	122.97	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.78	0.78	
KLM2	0.78	0.78	
KLM3	0.78	0.78	
KLM4	0.78	0.78	
KLM5	0.78	0.78	
Stiffness			
K1	0.564	0.564	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	1.198	1.198	psi
R2	1.198	1.198	psi
R3	1.198	1.198	psi
R4	1.198	1.198	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	2.124	2.124	in
Yield Line Distance		192	in

Analysis Parameters		
Natural period	81.94	ms
Time step	0.10	ms
Duration	188.88	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

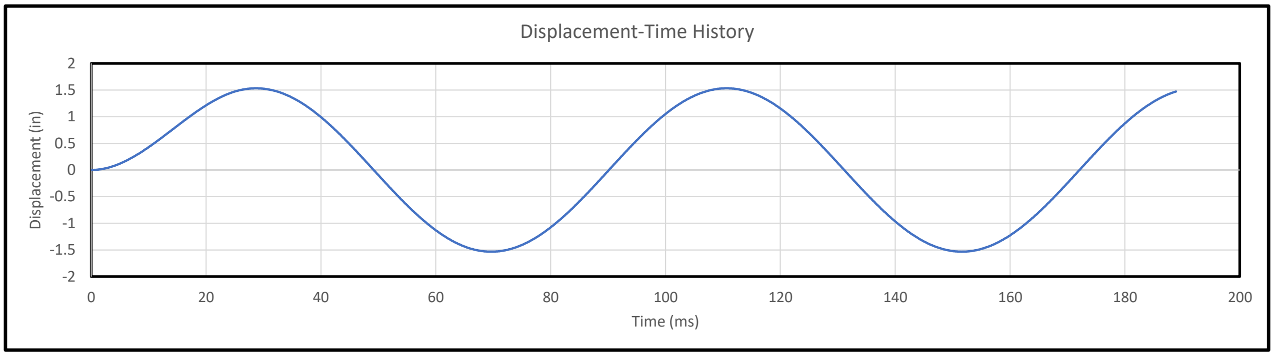
Results Summary				
Max. Defl. (in)	1.533	Max Supp. Rot.	0.46	deg
Time to Max. Resp. (ms)	28.700	Max Ductility	0.72	
Time to Yield Defl. (ms)	Ductility<1			
		Max Inbound Resist	0.86	psi
		Max Rebound Resist	-0.86	psi

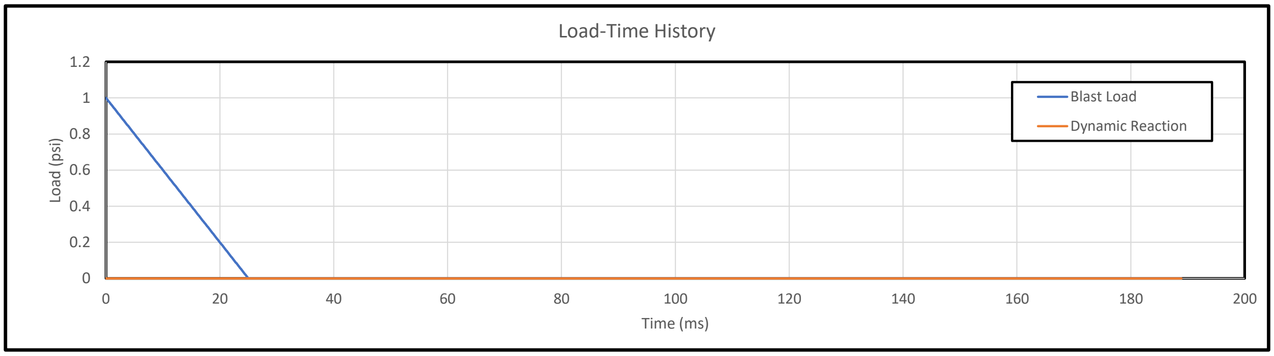
No Criteria Specified

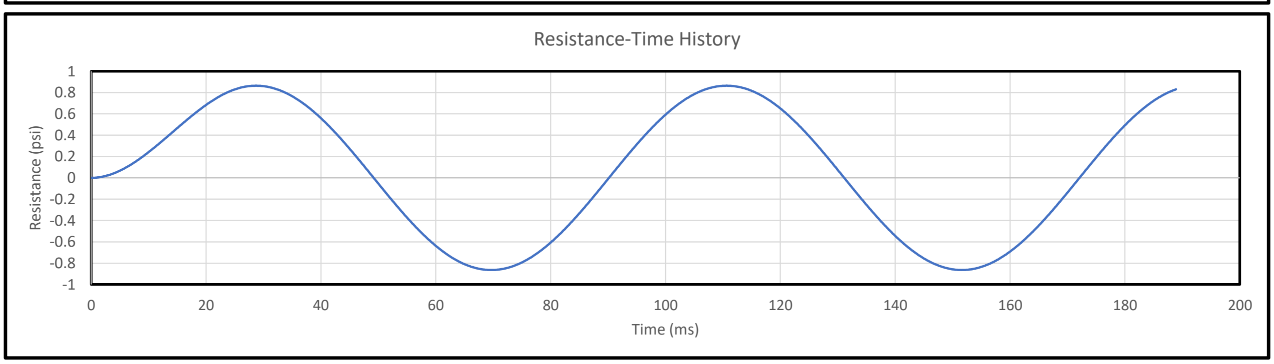
Project/Location UFC 3-340-02 | Building Validation Study | Component 5A-5(b)

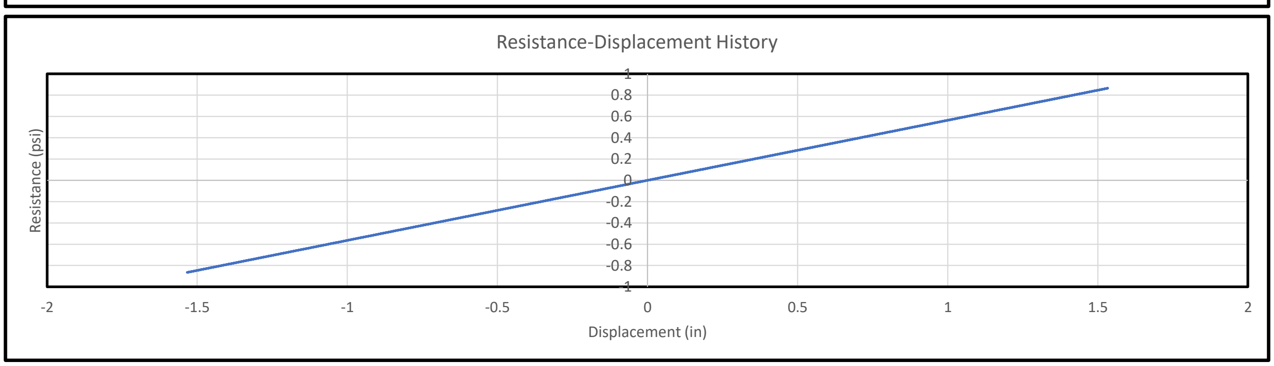
Analyzed By SMD | Date 8/4/2023

Results Summary						
Max. Defl. (in)	1.533	Max Supp. Rot.	0.46	deg	No Criteria Specified
Time to Max. Resp. (ms)	28.7	Max Ductility	0.72		
Time to Yield Defl. (ms)	Ductility<1				
		Max Inbound Resist	0.86	psi	
		Max Rebound Resist	-0.86	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 5A-6

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	216
78	0
78	0
78	0
78	0
78	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	53170	53170	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	1.8181818	1.8181818	
KLM2	1.8181818	1.8181818	
KLM3	1.8181818	1.8181818	
KLM4	1.8181818	1.8181818	
KLM5	1.8181818	1.8181818	
Stiffness			
K1	50.2	50.2	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	135	135	psi
R2	135	135	psi
R3	135	135	psi
R4	135	135	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	2.689	2.689	in
Yield Line Distance		192	in

Analysis Parameters		
Natural period	275.73	ms
Time step	0.10	ms
Duration	629.45	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

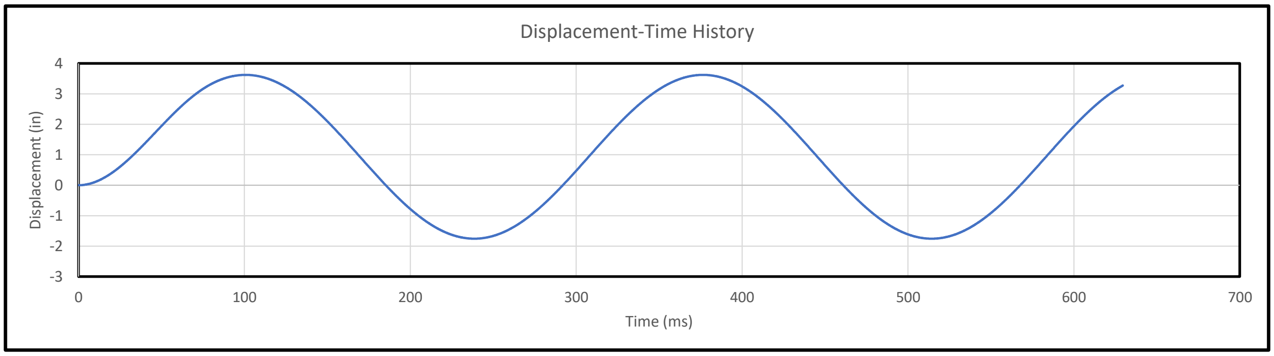
Results Summary

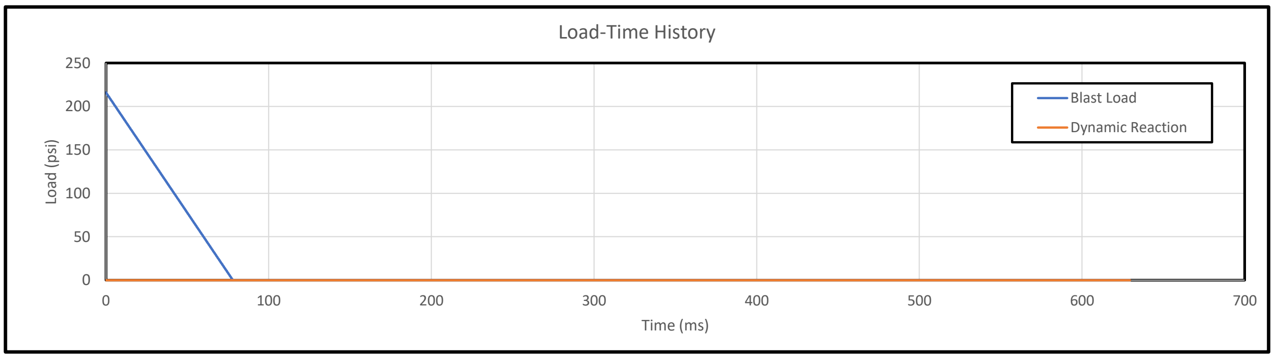
Max. Defl. (in)	3.623	Max Supp. Rot.	1.08	deg	No Criteria Specified
Time to Max. Resp. (ms)	100.700	Max Ductility	1.35		
Time to Yield Defl. (ms)	63.900				
		Max Inbound Resist	135.00	psi	
		Max Rebound Resist	-135.00	psi	

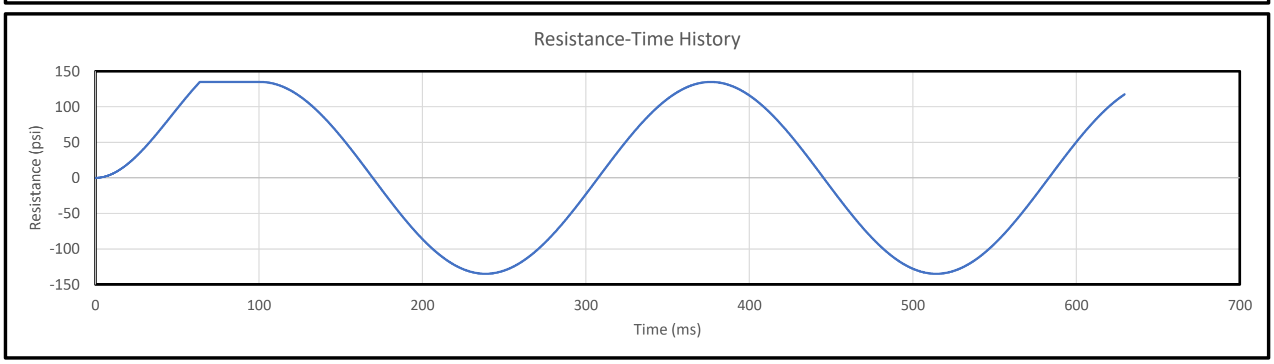
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-6
		Analyzed By	SMD	Date	8/4/2023

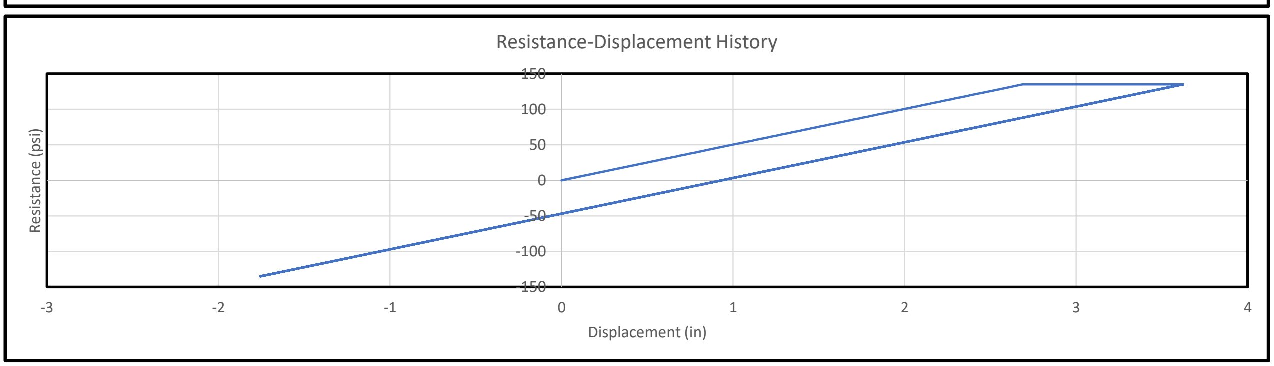
Results Summary

Max. Defl. (in)	3.623	Max Supp. Rot.	1.08	deg	No Criteria Specified
Time to Max. Resp. (ms)	100.7	Max Ductility	1.35		
Time to Yield Defl. (ms)	63.9				
		Max Inbound Resist	135.00	psi	
		Max Rebound Resist	-135.00	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 5A-6 (roof)

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	2.5
78	0
78	0
78	0
78	0
78	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	280.38	280.38	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.715	0.715	
KLM2	0.715	0.715	
KLM3	0.715	0.715	
KLM4	0.715	0.715	
KLM5	0.715	0.715	
Stiffness			
K1	8.219	8.219	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	3.119	3.119	psi
R2	3.119	3.119	psi
R3	3.119	3.119	psi
R4	3.119	3.119	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.379	0.379	in
Yield Line Distance		99	in

Analysis Parameters		
Natural period	31.03	ms
Time step	0.10	ms
Duration	140.06	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

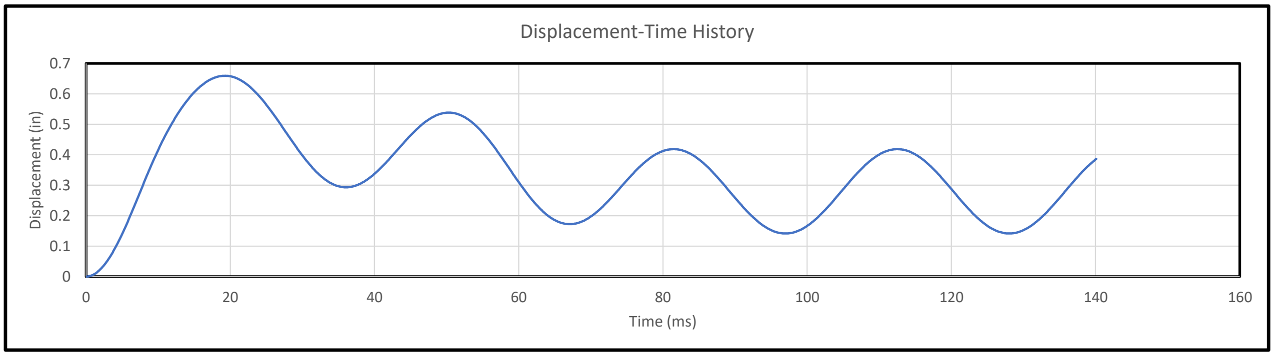
Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

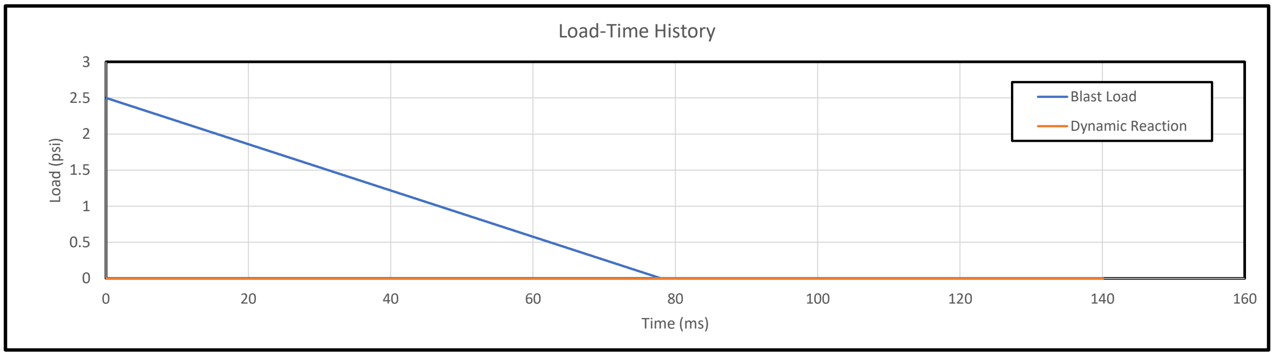
Results Summary

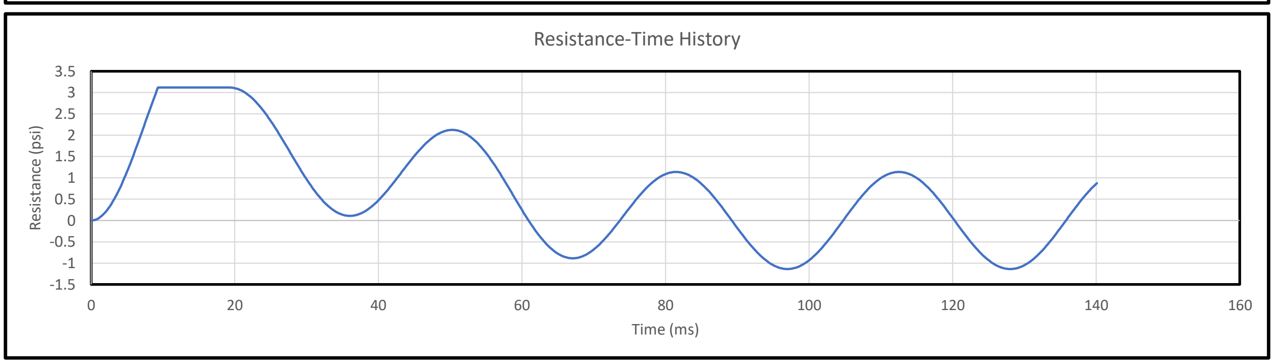
Max. Defl. (in)	0.659	Max Supp. Rot.	0.38	deg	No Criteria Specified
Time to Max. Resp. (ms)	19.300	Max Ductility	1.74		
Time to Yield Defl. (ms)	9.300				
		Max Inbound Resist	3.12	psi	
		Max Rebound Resist	-1.14	psi	

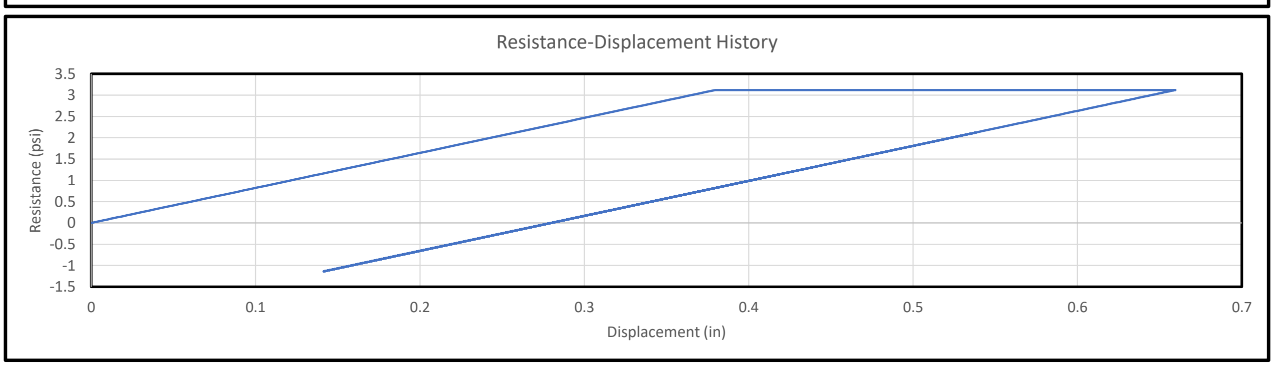
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-6 (roof)
		Analyzed By	SMD	Date	8/4/2023

Results Summary					
Max. Defl. (in)	0.659	Max Supp. Rot.	0.38	deg	No Criteria Specified
Time to Max. Resp. (ms)	19.3	Max Ductility	1.74		
Time to Yield Defl. (ms)	9.3				
		Max Inbound Resist	3.12	psi	
		Max Rebound Resist	-1.14	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-6 (Column)
Command Prompt:		Analyzed By	SMD	Date	8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	5.966
78	0
78	0
78	0
78	0
78	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	385.896	385.896	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	17.538	17.538	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	7.631	7.631	psi
R2	7.631	7.631	psi
R3	7.631	7.631	psi
R4	7.631	7.631	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.435	0.435	in
Yield Line Distance		91	in

Analysis Parameters		
Natural period	25.01	ms
Time step	0.10	ms
Duration	128.02	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

Results Summary

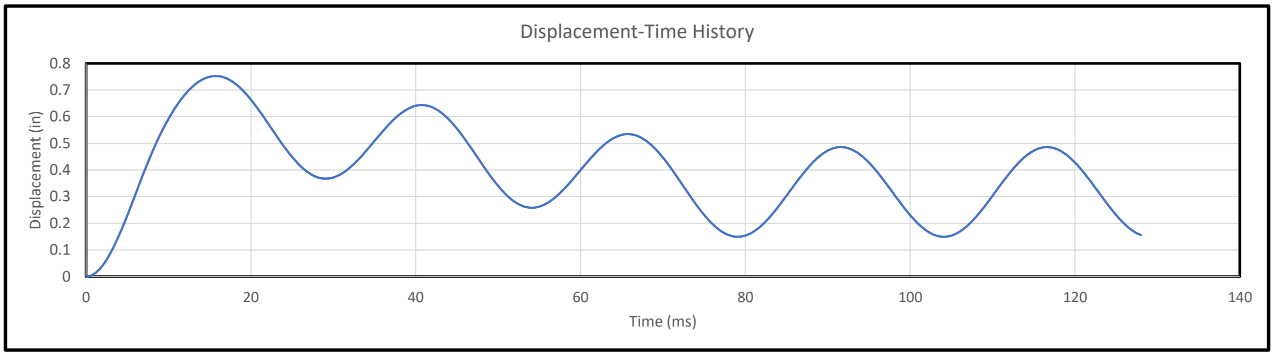
Max. Defl. (in)	0.753	Max Supp. Rot.	0.47	deg
Time to Max. Resp. (ms)	15.700	Max Ductility	1.73	
Time to Yield Defl. (ms)	7.600			
		Max Inbound Resist	7.63	psi
		Max Rebound Resist	-2.95	psi

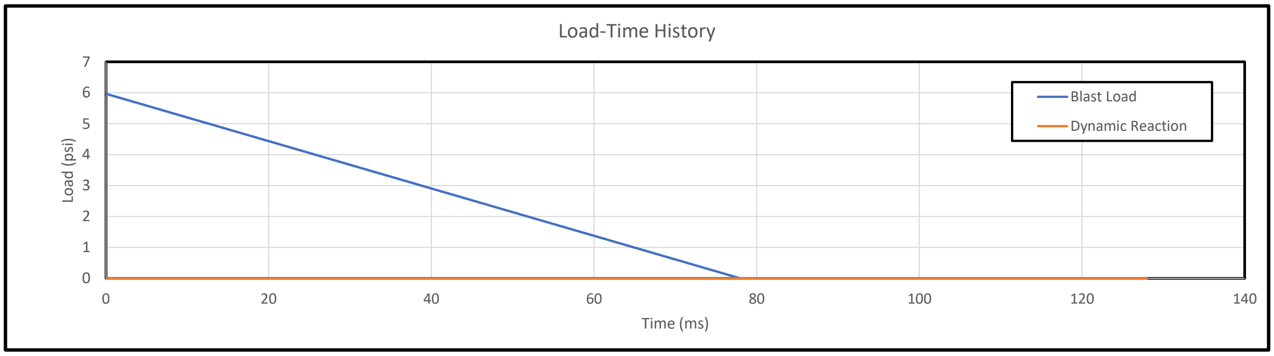
No Criteria Specified

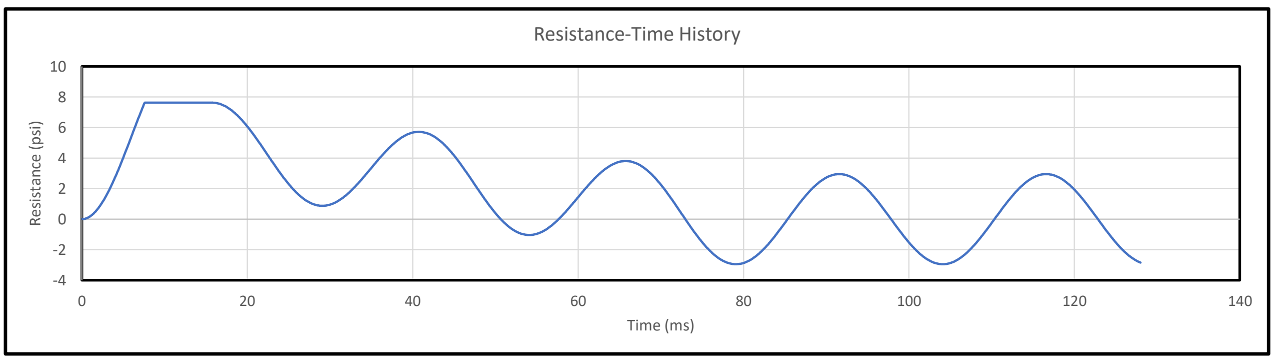
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-6 (Column)
		Analyzed By	SMD	Date	8/4/2023

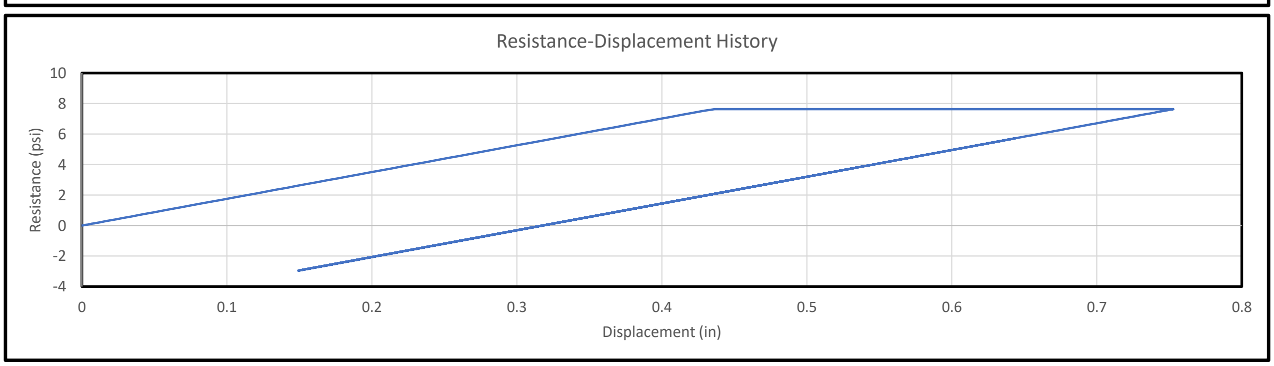
Results Summary

Max. Defl. (in)	0.753	Max Supp. Rot.	0.47	deg	No Criteria Specified
Time to Max. Resp. (ms)	15.7	Max Ductility	1.73		
Time to Yield Defl. (ms)	7.6				
		Max Inbound Resist	7.63	psi	
		Max Rebound Resist	-2.95	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-7(a) (Plate)
Command Prompt:		Analyzed By	SMD	Date	8/4/2023

Blast Load

User-Defined	
Time (ms)	Pressure (psi)
0	14.8
13	0
13	0
13	0
13	0
13	0

Constant Load (psi)	0

Response Criteria

User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters

Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties

Property	Inbound	Rebound	Units
Mass	458	458	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	27	27	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	25.7	25.7	psi
R2	25.7	25.7	psi
R3	25.7	25.7	psi
R4	25.7	25.7	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.952	0.952	in
Yield Line Distance		18	in

Analysis Parameters

Natural period	21.96	ms
Time step	0.10	ms
Duration	56.92	ms

Initial Conditions

Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters

% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients

User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

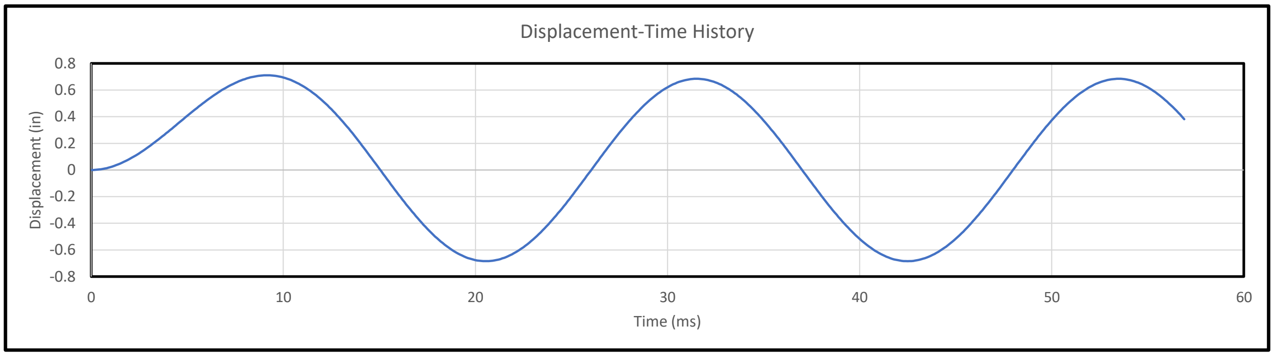
Results Summary

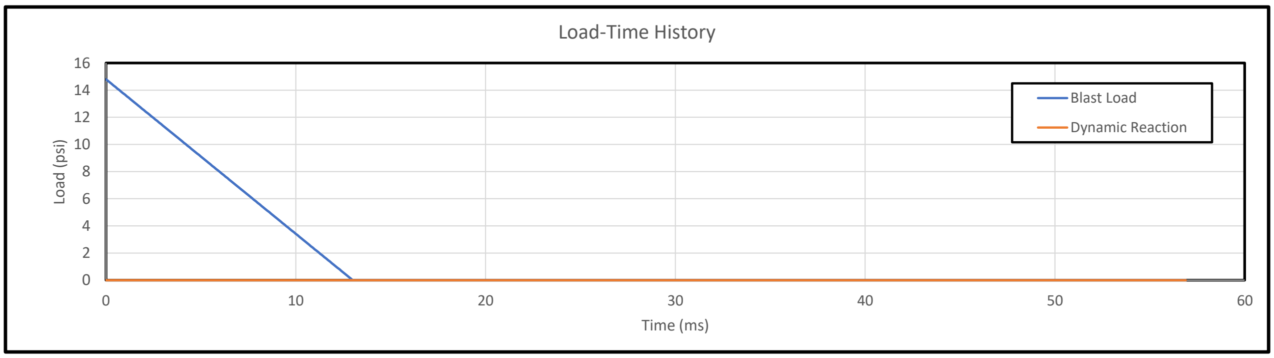
Max. Defl. (in)	0.711	Max Supp. Rot.	2.26	deg
Time to Max. Resp. (ms)	9.100	Max Ductility	0.75	
Time to Yield Defl. (ms)	Ductility<1			
		Max Inbound Resist	19.19	psi
		Max Rebound Resist	-18.48	psi

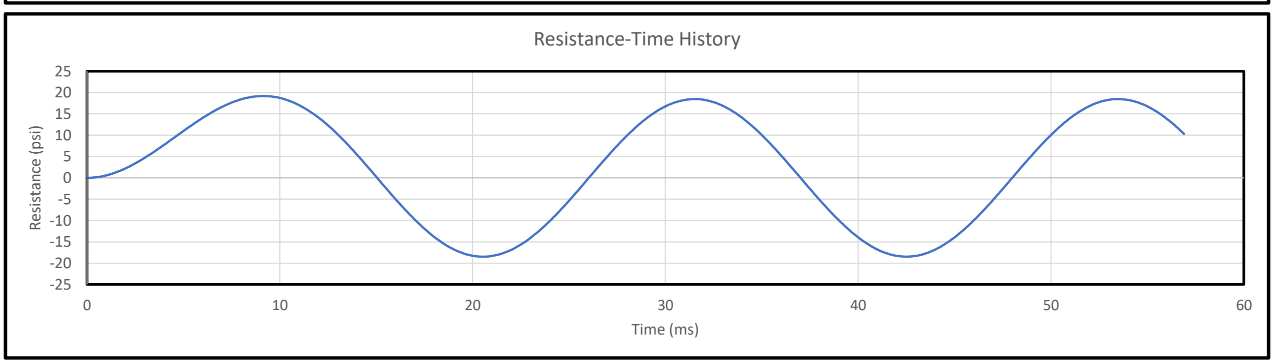
No Criteria Specified

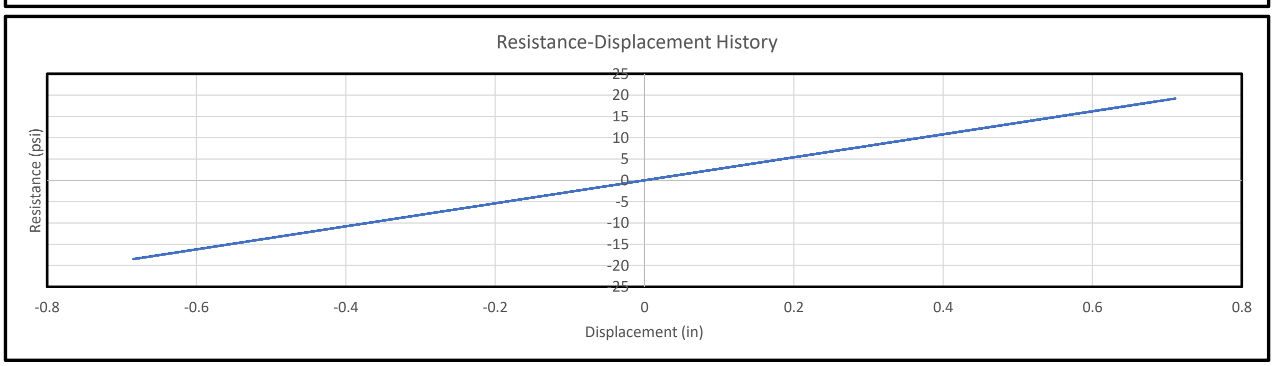
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-7(a) (Plate)
		Analyzed By	SMD	Date	8/4/2023

Results Summary					
Max. Defl. (in)	0.711	Max Supp. Rot.	2.26	deg	No Criteria Specified
Time to Max. Resp. (ms)	9.1	Max Ductility	0.75		
Time to Yield Defl. (ms)	Ductility<1				
		Max Inbound Resist	19.19	psi	
		Max Rebound Resist	-18.48	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-7(a)
Command Prompt:		Analyzed By	SMD	Date	8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	266.4
13	0
13	0
13	0
13	0
13	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	12361	12361	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	652.5	652.5	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	405	405	psi
R2	405	405	psi
R3	405	405	psi
R4	405	405	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.621	0.621	in
Yield Line Distance		48	in

Analysis Parameters		
Natural period	23.21	ms
Time step	0.10	ms
Duration	59.41	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

Results Summary

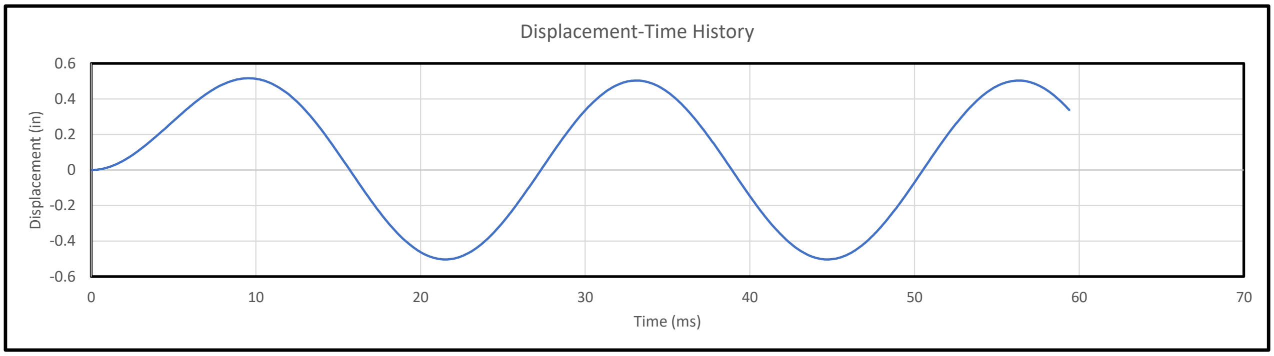
Max. Defl. (in)	0.516	Max Supp. Rot.	0.62	deg
Time to Max. Resp. (ms)	9.600	Max Ductility	0.83	
Time to Yield Defl. (ms)	Ductility<1			
		Max Inbound Resist	336.92	psi
		Max Rebound Resist	-328.58	psi

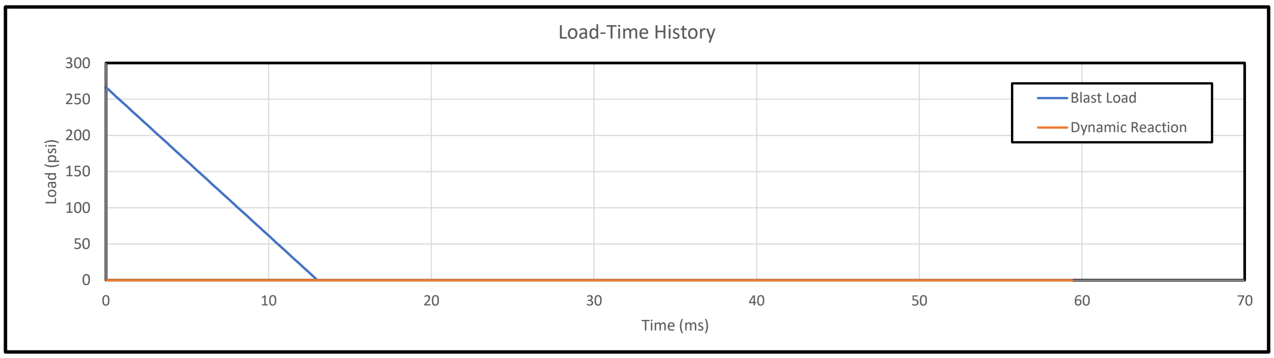
No Criteria Specified

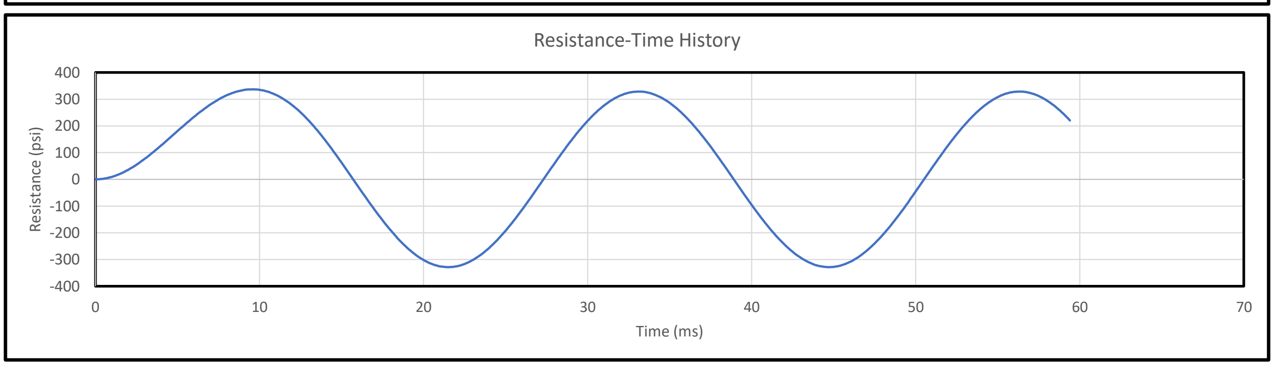
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-7(a)
		Analyzed By	SMD	Date	8/4/2023

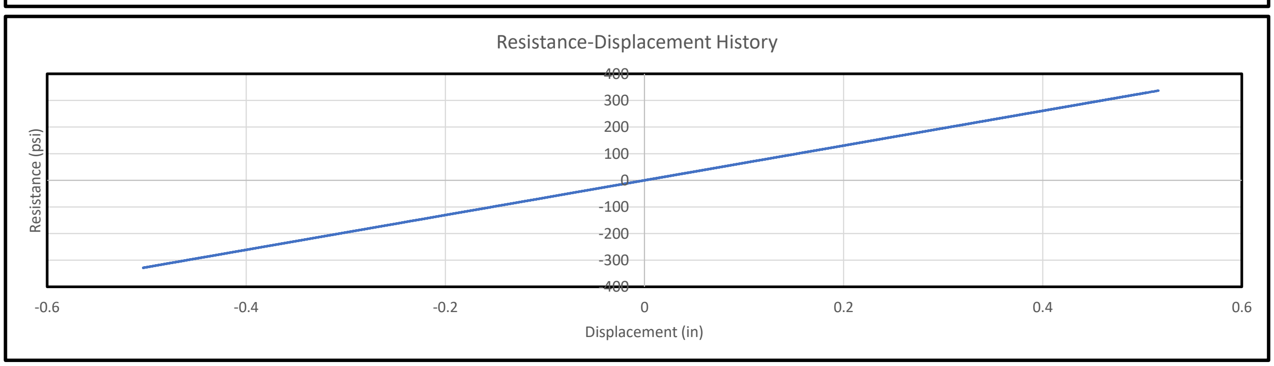
Results Summary

Max. Defl. (in)	0.516	Max Supp. Rot.	0.62	deg	No Criteria Specified
Time to Max. Resp. (ms)	9.6	Max Ductility	0.83		
Time to Yield Defl. (ms)	Ductility<1				
		Max Inbound Resist	336.92	psi	
		Max Rebound Resist	-328.58	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-7(b)
Command Prompt:		Analyzed By	SMD	Date	8/4/2023

Blast Load

User-Defined	
Time (ms)	Pressure (psi)
0	1000
1	0
1	0
1	0
1	0
1	0

Constant Load (psi)	100

Response Criteria

User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters

Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties

Property	Inbound	Rebound	Units
Mass	1468	1468	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	492	492	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	329	329	psi
R2	329	329	psi
R3	329	329	psi
R4	329	329	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.669	0.669	in
Yield Line Distance		24	in

Analysis Parameters

Natural period	9.21	ms
Time step	0.03	ms
Duration	19.42	ms

Initial Conditions

Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters

% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients

User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

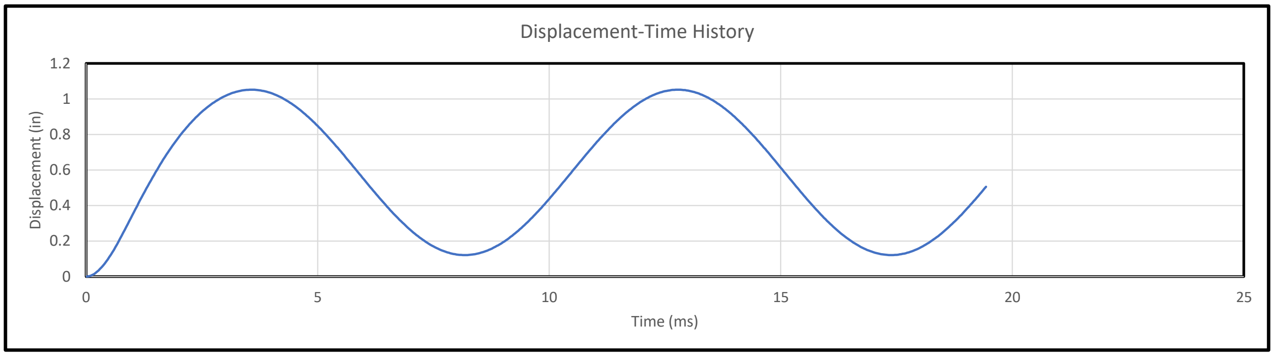
Results Summary

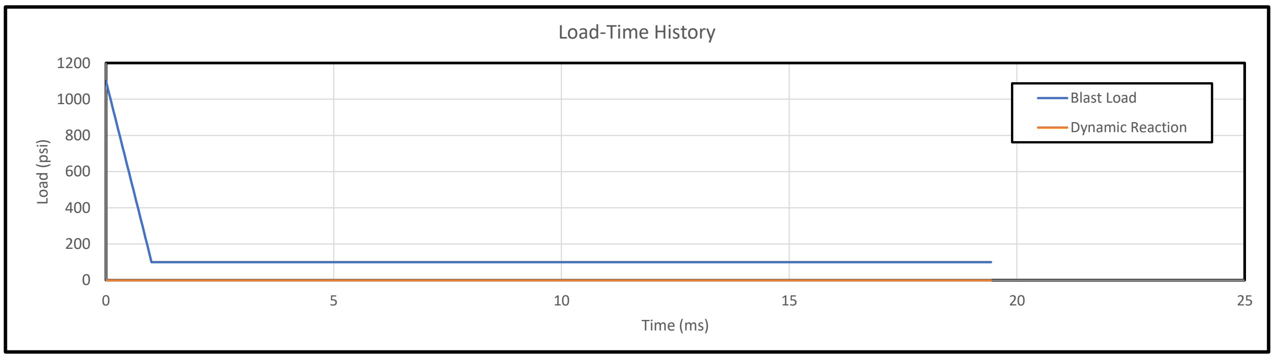
Max. Defl. (in)	1.052	Max Supp. Rot.	2.51	deg
Time to Max. Resp. (ms)	3.567	Max Ductility	1.57	
Time to Yield Defl. (ms)	1.700			
		Max Inbound Resist	329.00	psi
		Max Rebound Resist	-129.00	psi

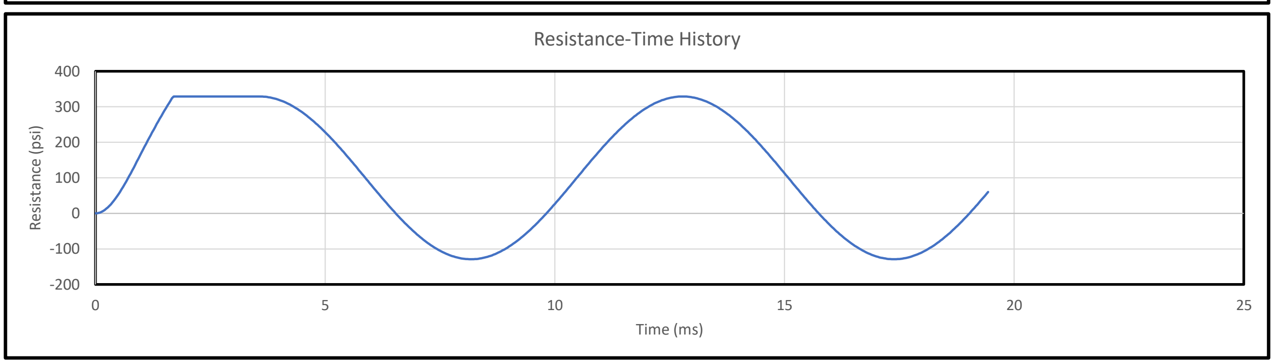
No Criteria Specified

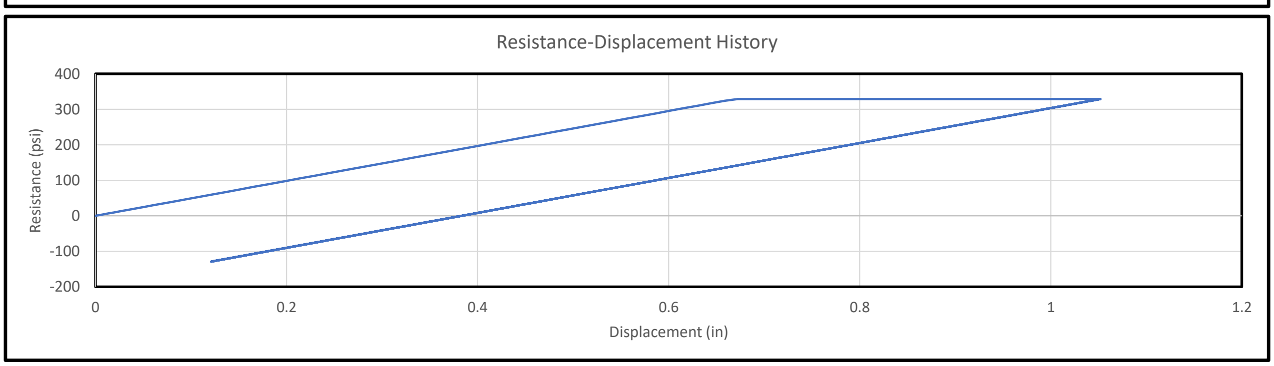
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-7(b)
		Analyzed By	SMD	Date	8/4/2023

Results Summary					
Max. Defl. (in)	1.052	Max Supp. Rot.	2.51	deg	No Criteria Specified
Time to Max. Resp. (ms)	3.566666667	Max Ductility	1.57		
Time to Yield Defl. (ms)	1.7				
		Max Inbound Resist	329.00	psi	
		Max Rebound Resist	-129.00	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 5A-8

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	4.5
20	0
20	0
20	0
20	0
20	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	238.15	238.15	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	2.1815	2.1815	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	5.926	5.926	psi
R2	5.926	5.926	psi
R3	5.926	5.926	psi
R4	5.926	5.926	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	2.716	2.716	in
Yield Line Distance		114	in

Analysis Parameters		
Natural period	55.70	ms
Time step	0.10	ms
Duration	131.41	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

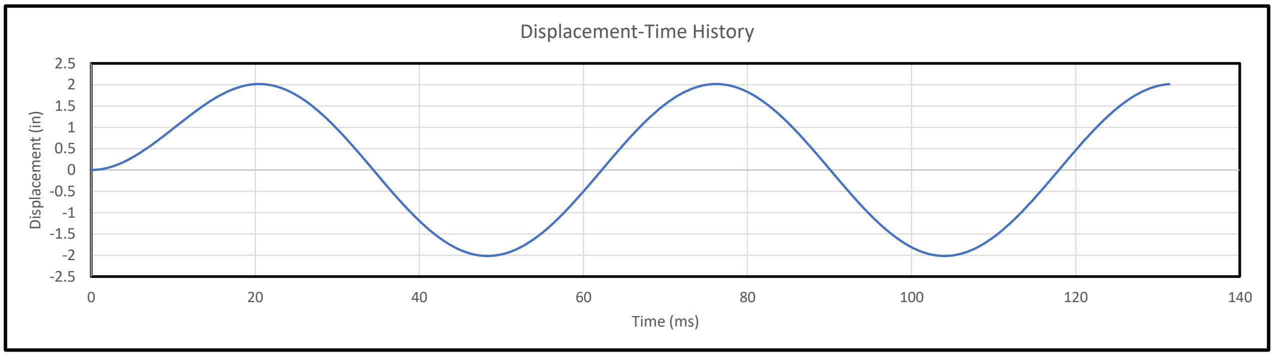
Results Summary				
Max. Defl. (in)	2.016	Max Supp. Rot.	1.01	deg
Time to Max. Resp. (ms)	48.300	Max Ductility	0.74	
Time to Yield Defl. (ms)	Ductility<1			
		Max Inbound Resist	4.40	psi
		Max Rebound Resist	-4.40	psi

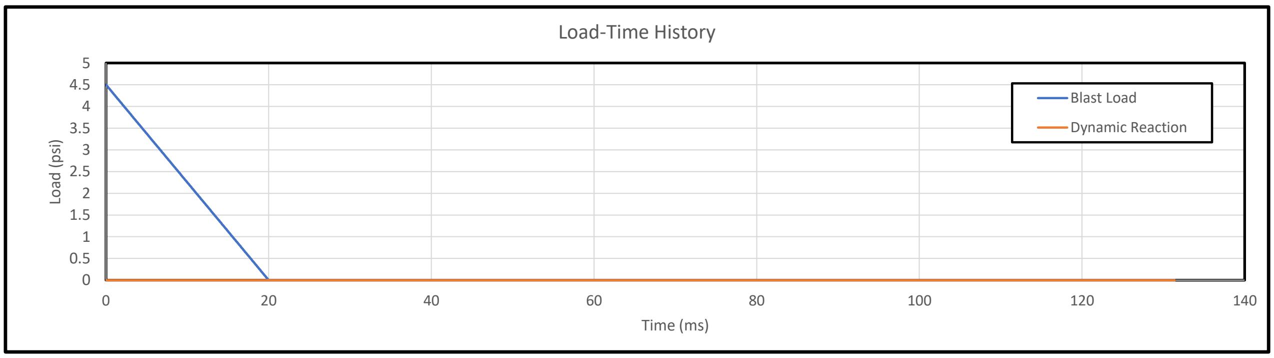
No Criteria Specified

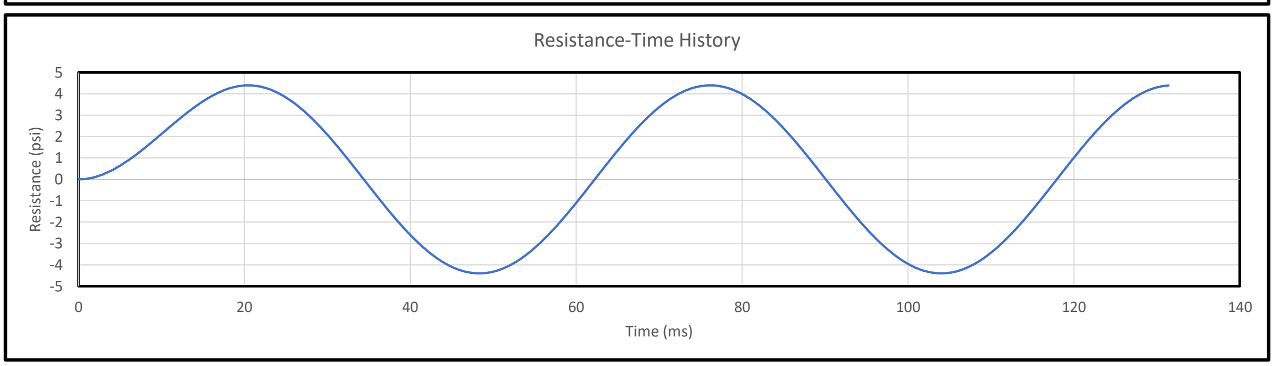
- Maximum Response in Rebound Phase - - Maximum Ductility in Rebound Phase -

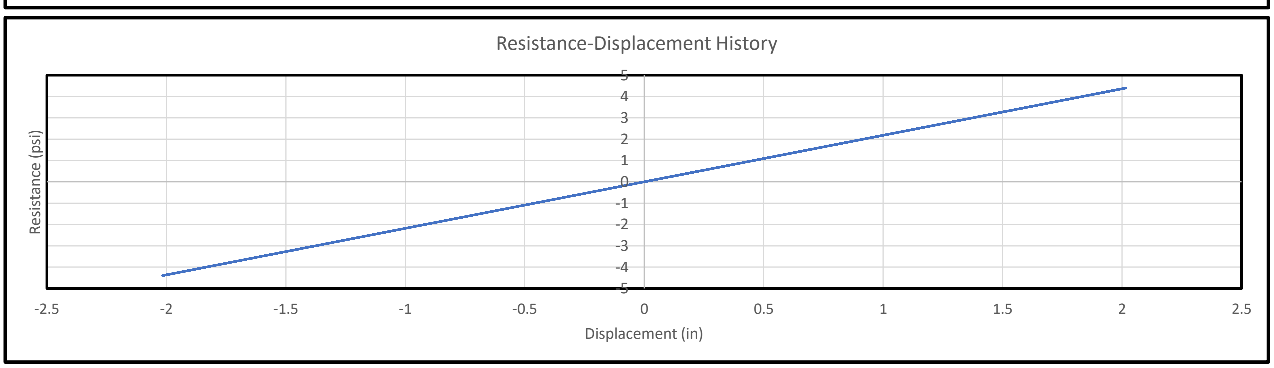
Project/Location	UFC 3-340-02	Building	Validation Study	Component	5A-8
		Analyzed By	SMD	Date	8/4/2023

Results Summary						
Max. Defl. (in)	2.016	Max Supp. Rot.	1.01	deg	No Criteria Specified	
Time to Max. Resp. (ms)	48.3	Max Ductility	0.74			
Time to Yield Defl. (ms)	Ductility<1					
		Max Inbound Resist	4.40	psi	- Maximum Response in Rebound Phase - - Maximum Ductility in Rebound Phase -	
		Max Rebound Resist	-4.40	psi		









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 6A-1

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	2
100	0
100	0
100	0
100	0
100	0

Constant Load (psi)	0

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	981	981	$psi\text{-}ms^2/in$
Load Mass Factors			
User-Defined			
KLM1	0.72	0.72	
KLM2	0.72	0.72	
KLM3	0.72	0.72	
KLM4	0.72	0.72	
KLM5	0.72	0.72	
Stiffness			
K1	4.34	4.34	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	1.23	1.23	psi
R2	1.23	1.23	psi
R3	1.23	1.23	psi
R4	1.23	1.23	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	0.283	0.283	in
Yield Line Distance		75	in

Analysis Parameters		
Natural period	80.16	ms
Time step	0.10	ms
Duration	260.31	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.000	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

Results Summary				
Max. Defl. (in)	2.439	Max Supp. Rot.	1.86	deg
Time to Max. Resp. (ms)	90.500	Max Ductility	8.61	
Time to Yield Defl. (ms)	15.500			
		Max Inbound Resist	1.23	psi
		Max Rebound Resist	-1.21	psi

No Criteria Specified

Project/Location UFC 3-340-02

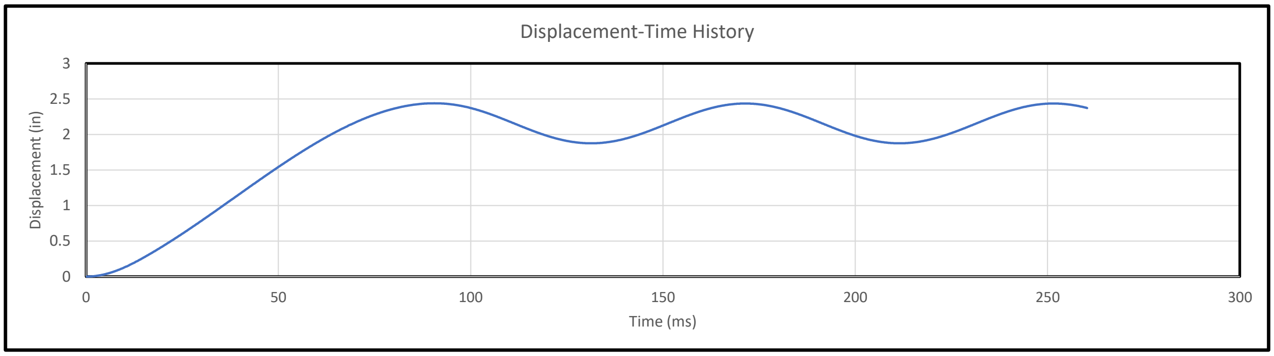
Building Validation Study

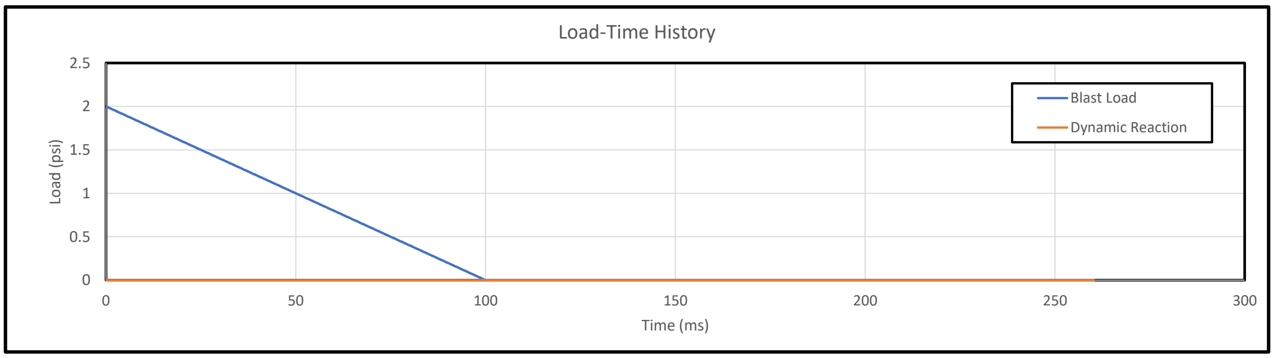
Component 6A-1

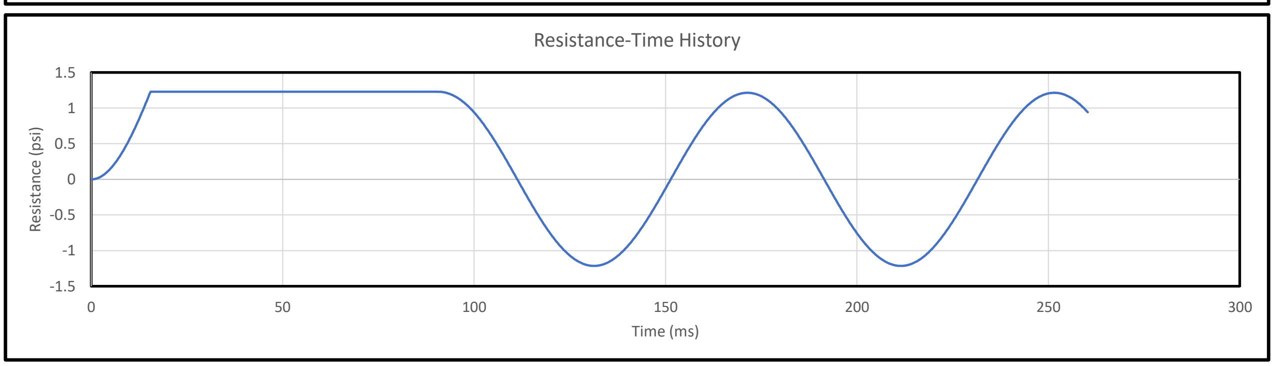
Analyzed By SMD

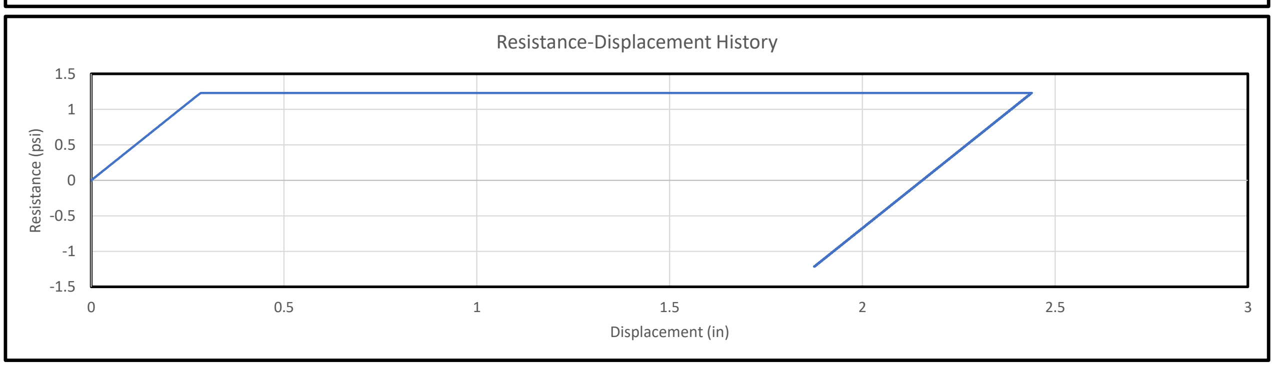
Date 8/4/2023

Results Summary					
Max. Defl. (in)	2.439	Max Supp. Rot.	1.86	deg	No Criteria Specified
Time to Max. Resp. (ms)	90.5	Max Ductility	8.61		
Time to Yield Defl. (ms)	15.5				
		Max Inbound Resist	1.23	psi	
		Max Rebound Resist	-1.21	psi	









NAVFAC EXWC SDOF Dynamic Analysis Spreadsheet

Project/Location: UFC 3-340-02 | Building: Validation Study | Component: 6A-2

Command Prompt: | Analyzed By: SMD | Date: 8/4/2023

Blast Load	
User-Defined	
Time (ms)	Pressure (psi)
0	1.1
43.9	0
43.9	0
43.9	0
43.9	0
43.9	0

Constant Load (psi)	0.553

Response Criteria	
User-Defined	
Support Rotation (deg)	
Max Ductility	
Max Displacement (in)	

2-Way Parameters	
Height	
Length	
Yield Line Dist (y)	
Yield Line Dist (x)	

Height must be Short Span (For 2 or 4-side supports) or Unsupported Span (for 3-side Supports)

SDOF Properties			
Property	Inbound	Rebound	Units
Mass	1162.5	1162.5	psi-ms^2/in
Load Mass Factors			
User-Defined			
KLM1	0.78	0.78	
KLM2	0.78	0.78	
KLM3	0.78	0.78	
KLM4	0.78	0.78	
KLM5	0.78	0.78	
Stiffness			
K1	0.8776	0.8776	psi/in
K2	0	0	psi/in
K3	0	0	psi/in
K4	0	0	psi/in
Resistance			
R1	1.29	1.29	psi
R2	1.29	1.29	psi
R3	1.29	1.29	psi
R4	1.29	1.29	psi
Displacement			
Stiffness Controlled			
X1	0	0	
X2	0	0	
X3	0	0	
X4	0	0	
Equiv. Elastic Displ.	1.470	1.470	in
Yield Line Distance		75	in

Analysis Parameters		
Natural period	201.96	ms
Time step	0.10	ms
Duration	447.83	ms

Initial Conditions		
Initial Vel.	0	in/ms
Initial Displ.	0.630	in

Damping Parameters		
% of Crit. Damp.	0	%
Elasto-plastic Damping	Yes	

Dynamic Reaction Coefficients		
User-Defined		
Reaction 1	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		
Reaction 2	Force	Resistance
Elastic		
Elasto-Plastic		
Plastic		

Results Summary

Max. Defl. (in)	1.443	Max Supp. Rot.	1.10	deg
Time to Max. Resp. (ms)	267.000	Max Ductility	0.98	
Time to Yield Defl. (ms)	Ductility<1			
		Max Inbound Resist	1.27	psi
		Max Rebound Resist	-0.16	psi

No Criteria Specified

Project/Location UFC 3-340-02 | Building Validation Study | Component 6A-2

Analyzed By SMD | Date 8/4/2023

Results Summary						
Max. Defl. (in)	1.443	Max Supp. Rot.	1.10	deg		No Criteria Specified
Time to Max. Resp. (ms)	267	Max Ductility	0.98			
Time to Yield Defl. (ms)	Ductility<1					
		Max Inbound Resist	1.27	psi		
		Max Rebound Resist	-0.16	psi