NIST Technical Note 2001

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Introductory Tutorial for DAD: Design Examples of High-Rise Building for Wind

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Abstract

This report presents the introductory tutorials for the users of the software DAD_ESWL v1.0 capable of computing efficiently the response to wind of mid- and high-rise structures consisting of up to thousands of members. The five example projects including step-by-step instructions in this report guide the users how to work with the software. To more fully grasp the use of the software, the users should use this introductory tutorial in conjunction with NIST Technical Note 2000, including the User's Manual contained therein.

Contents

Chapter 1. Introduction

1.1 Overview of DAD and ESWL

Database-assisted procedure as applied to mid- and high-rise buildings entails the phases represented in Fig. 1. Note in Fig. 1 that two such procedures for determining the structural response are available: the Database-Assisted Design (DAD) procedure properly so called, in which the time-dependent loads are used directly to calculate the structural response, and the Equivalent Static Wind Loads (ESWL) procedure, in which static loads whose effects on the structure are approximately equivalent to the effects induced by DAD are determined from time series of time-dependent loads, and are then used to calculate the structural response. The processes within the dotted box constitute the main algorithm of the latest version of the software, *DAD_ESWL v1.0*.

DAD_ESWL v1.0 is a stand-alone MATLAB[1]-based software capable of computing efficiently the response to wind of mid- and high-rise structures consisting of up to thousands of members. The software calculates the structural responses induced by wind loads, including internal forces in members, member interaction formulas based on demand-to-capacity indexes, inter-story drifts, and accelerations, for any specified mean recurrence interval of the wind effects being considered.

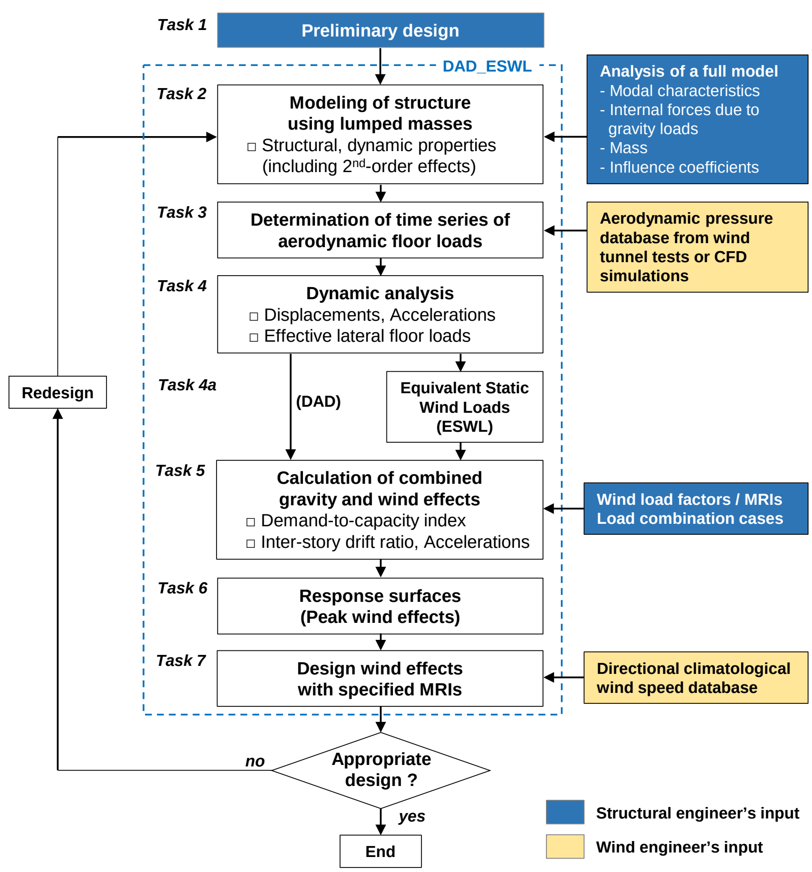


Figure 1. DAD and ESWL procedures

[1] MATLAB®. © 1994 – 2018 The MathWorks, Inc.

1.2 Overview of this tutorial

This tutorial introduces users to *DAD_ESWL v1.0*. Step-by-step instructions based on the seven tasks of the DAD and ESWL procedures represented in Fig. 1 guide the users through example projects on how to work with the software. Input data files for the example projects being considered in this tutorial are provided separately on the website http://nist.gov/wind. To more fully grasp the use of *DAD_ESWL*, the reader should use this introductory tutorial in conjunction with NIST Technical Note 2000, including the User's Manual contained therein.

A total of four example projects are included in this tutorial as follows:

Chapter	Project Title	Options to Use						
		DAD	ESWL	P-Δ effects	Floor wind load calc.[1)]	OpenSees[2)]	Climatological data	
							1 (NIST hurricanes)	2 (Synoptic)
3	**60-story steel building I**	✓		✓			✓	
4	**60-story steel building II**	✓				✓	✓	✓
5	**60-story RC[3)] building**	✓		✓				✓
6	**47-story steel building I**		✓	✓	✓		✓	
7	**47-story steel building II**	✓		✓	✓		✓	

[1)] The user has two options for calculation of aerodynamic wind loading. One option, used in Chapter 6, is explained in and is embedded in the software. The second option allows the user to implement his or her own algorithm for calculating the aerodynamic wind loading.
[2)] Option for using OpenSees to obtain building's structural data internally in DAD_ESWL software.
[3)] Reinforced concrete

Chapter 2. Getting started

2.1 Before you begin

The software should be installed on your computer. *DAD_ESWL* can be accessed via the website http://nist.gov/wind. The stand-alone executable version of the *DAD_ESWL* software requires installation of **MCRInstaller.exe**, which is also available on the website. The website also includes the input data files for the example project described in the following sections of this introductory tutorial.

To run the software, we recommend that a folder for your design project, e.g., '*Project_Name*', be created on your local drive C to save all downloaded files and folders. A recommended directory structure is shown in Fig. 2. The executable file for the software (**DAD_ESWL_v1p0.exe**) should be in each project directory. The '*Aerodynamic_data*' folder contains the data files (.DAT format) for wind pressures or floor wind loads from wind-tunnel testing or CFD simulation. The '*Building_data*' folder contains the building's structural data, i.e., members' properties, mass matrix, influence coefficients, internal forces of members induced by gravity loads, and modal properties. These building's structural data must be calculated and prepared in advance via arbitrary finite element software. If you would like to use OpenSees to obtain the building's structural data internally in *DAD_ESWL*, the '*OpenSees*' folder should be added. The 'OpenSees' folder contains the executable file of OpenSees (**OpenSees.exe**), the user's pre-defined Tcl file, and other mandatory data files related to run OpenSees during the use of *DAD_ESWL*. The '*Climatological_data_NISThurr*', '*Climatological_data_1*' and '*Climatological_data_2*' folders contain measured or simulated directional hurricane and non-hurricane wind speed data, respectively. After all computations have been completed, the results will be saved in the '*Output*' folder.

Depending upon the use of options for each example project, the directory structure might be changed. A more detailed directory structure will be introduced at the beginning of each chapter for the respective example project.

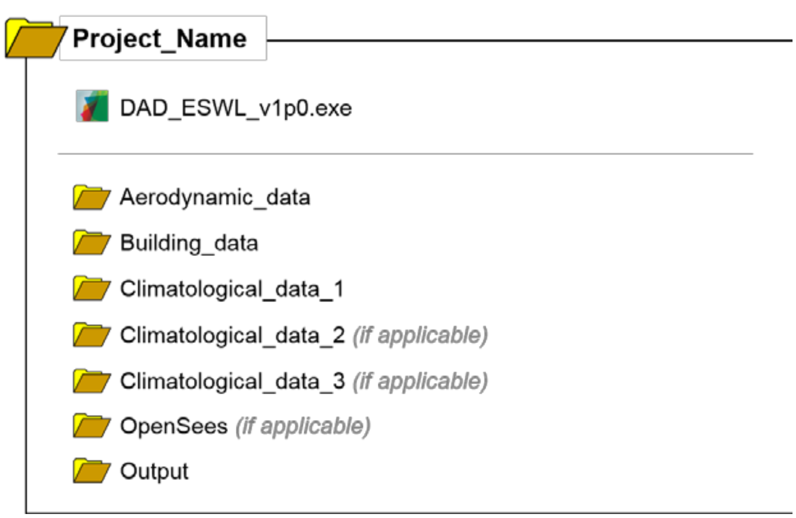


Figure 2. Directory structure

2.2 Graphical user interface

The layout of the graphical user interface of *DAD_ESWL* is shown in Fig. 3.

▪ Structure's type indicator: This indicator shows what the structure's type you chose in the initial page of *DAD_ESWL*. You cannot change the structure's type during the use of *DAD_ESWL*.

▪ Input panel: You can input necessary values, browse data files, and select options to be required to analyze in this panel.

▪ Input panel navigator: By clicking five buttons in this section, you can move onto each input panel. There are total five panels in *DAD_ESWL*, i.e., **Bldg. modeling**, **Wind loads**, **Resp. surface**, **Wind effects**, and **Results & Plots**, in order of analysis progress.

▪ Save input data: Click the **Save inputs** button to save input data as a MAT file to a directory you select whenever you want. This does NOT save analysis results. Only the input values, data file paths, and selected options will be saved for your future use of *DAD_ESWL*.

▪ Open input data file: Click the **Open inputs** button to load your previous input data saved as a MAT file. Empty boxes and unselected options in the input panels will be filled and activated after you open your saved input data.

▪ Exit software: Click the **Exit** button to terminate *DAD_ESWL* whenever you want.

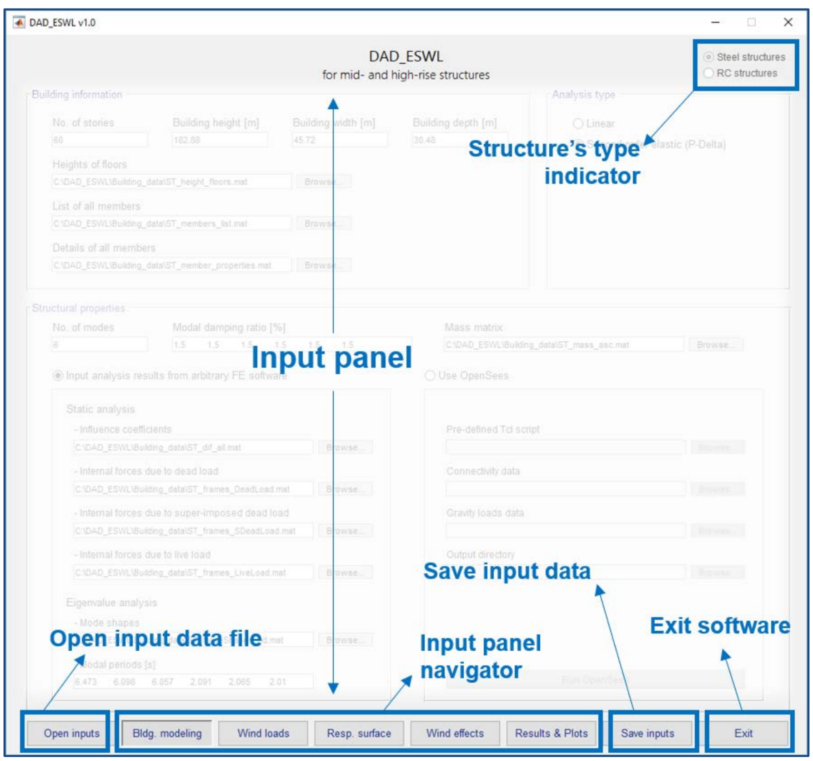


Figure 3. Graphical user interface of DAD_ESWL

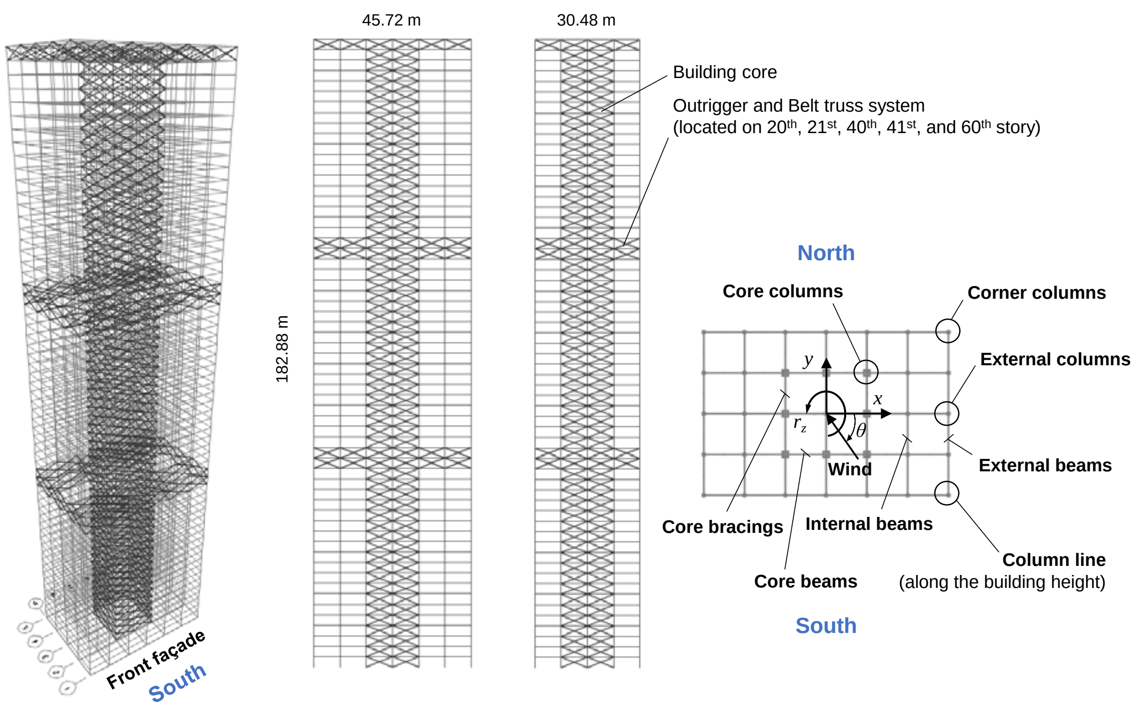
Chapter 3. Example project 1: 60-story steel building I

3.1 Project description

The example project 1 is a 60-story steel building, known as the CAARC building (Melbourne 1980), with floors assumed to be rigid diaphragms (Fig. 4). The building is 45.72 m in width, 30.48 m in depth, and 182.88 m in height, and its structure consists of 6 bays by 4 bays along the width and the depth, respectively. An outrigger and belt truss system is located at the 20^{th}, 21^{st}, 40^{th}, 41^{st}, and 60^{th} story. The structure contains 2100 columns, 3480 beams, and 2560 diagonal bracings. The building is assumed to be located on the suburban terrain near Miami, Florida. The orientation angle of the building is 270° clockwise from the north, that is, a front façade of the building faces north.

The building will be analyzed by implementing the DAD procedure with the use of randomly fluctuating wind loads acting at each floor, which were calculated in advance by the authors from the pressure coefficient data (Cp) obtained in the wind tunnel testing performed by Venanzi (2005). The multiple points-in-time (Yeo 2013) approach with 30 points will be applied. Second-order effects, i.e., *P-Δ* and *P-δ* effects, will be accounted for. The building will be analyzed for gravity and aerodynamic loads with the load combination 1.2*D* + 1.0*L* + 1.0*W* (denoted by LC1), where *D* is the total dead load, *L* is the live load, and *W* is the wind load.

To run the project, download a folder named '*Project_01*' from the website http://nist.gov/wind and save it on your local drive C shown in Fig 5.



(a) 3D view (b) Front view (c) Side view (d) Plan view (θ = wind direction)

Figure 4. 60-story steel building model I

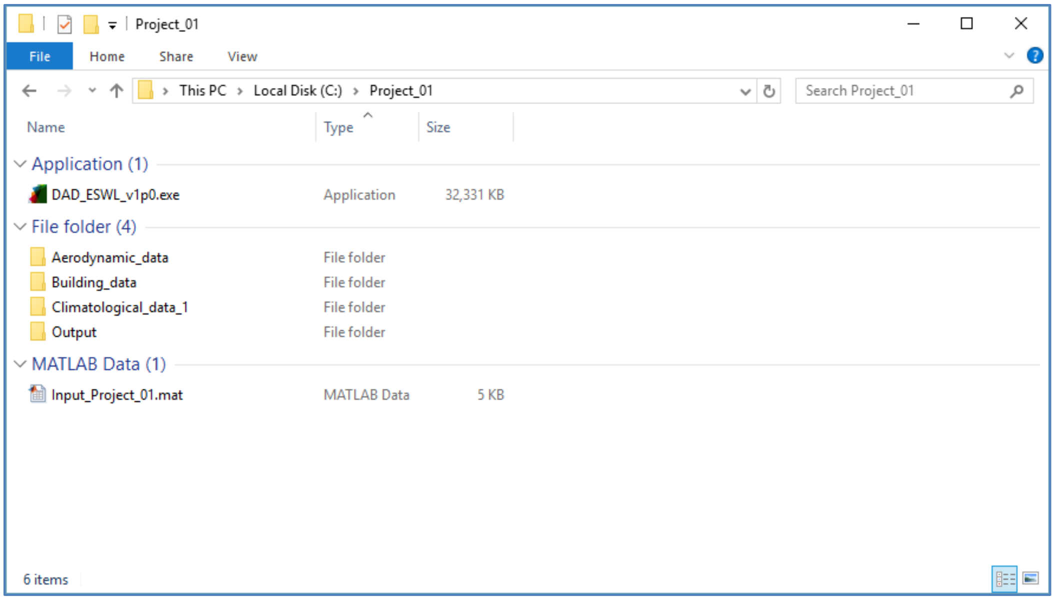


Figure 5. Directory structure for example project 1

Note that the '*Input_Project_01.mat'* file is not the mandatory file for running the software. However, this file is provided for the convenience of the users. It contains all the input values and file path values needed for the example project 1. The users can use this file through the 'Open inputs' button in the software.

3.2 Building's structural data

All the members' cross-sectional dimensions for the preliminary design, D_0, are listed in Table 1. *DAD_ESWL* requires additional sectional properties based on those dimensions, e.g., area, torsional constant, moment of inertia, shear area, and radius of gyration (see User's Manual in NIST Technical Note 2000 for details).

After obtaining initial dimensions of the structural members, influence coefficients, internal forces induced by gravity loads of the members, mass matrix, natural periods of vibration, and mode shapes should be calculated by modal analysis using a finite element analysis program. Table 2 lists the natural periods of vibration for the preliminary design D_0. The modal damping ratios are assumed to be 1.5 % in all six modes considered in this project.

The building's structural data are included in '*Building_data*' folder. Table 3 lists the structural data required to analyze this example project, and their file name and path.

Table 1. Members' cross-section dimensions (unit = mm)

Members' type	Section ID	Sectional type	Depth	Width	Flange thickness	Web thickness
Bracing	1	Box/Tube	500	300	15	15
	2	Box/Tube	400	300	15	15
	3	Box/Tube	300	250	12	12
Column	1	Box/Tube	700	700	50	50
	2	Box/Tube	600	600	50	50
	3	Box/Tube	600	600	40	40
	4	Box/Tube	600	600	30	30
	5	Box/Tube	500	500	20	20
	6	Box/Tube	400	400	15	15
	7	Box/Tube	1400	1400	50	50
	8	Box/Tube	1200	1200	50	50
	9	Box/Tube	1000	1000	50	50
	10	Box/Tube	800	800	40	40
	11	Box/Tube	600	600	30	30
	12	Box/Tube	400	400	20	20
Beam	1	I/Wide Flange	253.49	254.00	14.22	8.64

Table 2. Natural periods of vibration

Mode	1st	2nd	3rd	4th	5th	6th
Natural periods [s]	6.473	6.098	6.057	2.091	2.065	2.010

Table 3. Building's structural data

Structural data	File name	Path
Members' list	*ST_members_list.mat*	C:\Project_01\Building_data
Members' properties	*ST_member_properties.mat*	
Mass matrix	*ST_mass_asc.mat*	
Influence coefficients	*ST_dif_all.mat*	
Internal forces by dead load	*ST_frames_DeadLoad.mat*	
Internal forces by super-imposed dead load	*ST_frames_SDeadLoad.mat*	
Internal forces by live load	*ST_frames_LiveLoad.mat*	
Mode shapes	*ST_ModeShapes_pd.mat*	

3.3 Aerodynamic pressure data

The example building is assumed to have suburban terrain exposure. Time series of aerodynamic loads on each floor are calculated from pressure data induced by wind velocities with wind directions in 10° increments (0°, 10°, …, 350°). The pressure coefficients were measured in wind tunnel tests at the Prato (Italy) Inter-University Research Centre on Building Aerodynamics and Wind Engineering (CRIAC IV-DIC) Boundary Layer Wind Tunnel (Venanzi 2005).

The length scale of the aerodynamic model was 1:500. The duration of the records was 30 s with sampling frequency of 250 Hz for a total approximately 7500 samples for each pressure tap. The mean wind speed at top of the building model during the wind tunnel tests was 23.2 m/s. Since a numerical integration needs a certain number of points before it stabilizes, the first 200 points of the time series are not used in the DAD analysis.

The floor wind load data (*Fl_XXX.mat*, where *XXX* varies from '000' to '360' by in increments of 10) are included in '*Aerodynamic_data*' folder.

3.4 Climatological wind speed data

Structural responses to directional wind are obtained by making use of the directional wind speeds of the wind climatological database in conjunction with the response surfaces. The wind climatological database for the calculations presented in this example project is based on NIST hurricane database, a wind speed dataset of 999 simulated hurricanes for 16 directions near Miami, Florida (Milepost 1450). The wind speeds in the dataset correspond to knot at 10 m height above ground in the open terrain exposure.

Peak responses are obtained for the Demand-to-Capacity indexes (DCIs) corresponding to a 1700-year mean recurrence interval (MRI). Peak inter-story drift and accelerations of the building will be obtained from the peak response surfaces for MRI = 20 years and MRI = 10 years, respectively.

The wind climatological dataset (*Nhurr_Miami(182).mat* file for the milepost 1450) included in '*Climatological_data_1*' directory, is also available at http://nist.gov/wind.

3.5 Step-by-step tutorial for DAD_ESWL

This section provides step-by-step tutorial for the use of *DAD_ESWL* software to analyze the example building subjected to wind. The tutorial follows the seven tasks (steps) of the DAD procedure shown in Fig. 1.

Step 1. Begin a new model with preliminary design D_0

Select the structural system, and determine its preliminary member sizes by using a simplified model of the wind loading (e.g., a static wind loading based on standard provisions). The structural design so achieved is denoted by D_0.

Select the structural system

a. Run **DAD_ESWL_v1p0.exe**, select the **Steel Structure,** and click the **Start** button.

Note. Please wait until the initial page is open. It might take several minutes.

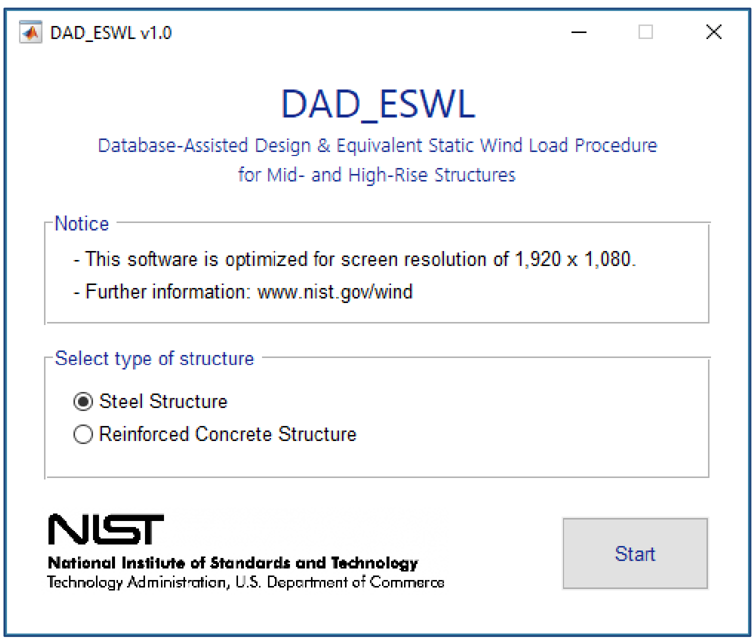


Figure 6. Structural type selection panel

The software will then display the main GUI of the **Bldg. modeling** input panel.

Building information and Analysis type panels:

a. Set the **No. of stories** to **60**.

b. Set the **Building height [m]** to **182.88**.

c. Set the **Building width [m]** to **45.72**.

d. Set the **Building depth [m]** to **30.48**.

e. Set the **Orientation angle [deg.]** to **270**.

f. Click the **Browse** button for **Heights of floors** section. Then select *ST_height_floors.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

g. Click the **Browse** button for **List of all members** section. Then select *ST_members_list.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

h. Click the **Browse** button for **Details of all members** section. Then select *ST_member_properties.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

k. Go to the **Analysis type** section on the right side. Select the **Second-order elastic (P-Delta)** toggle.

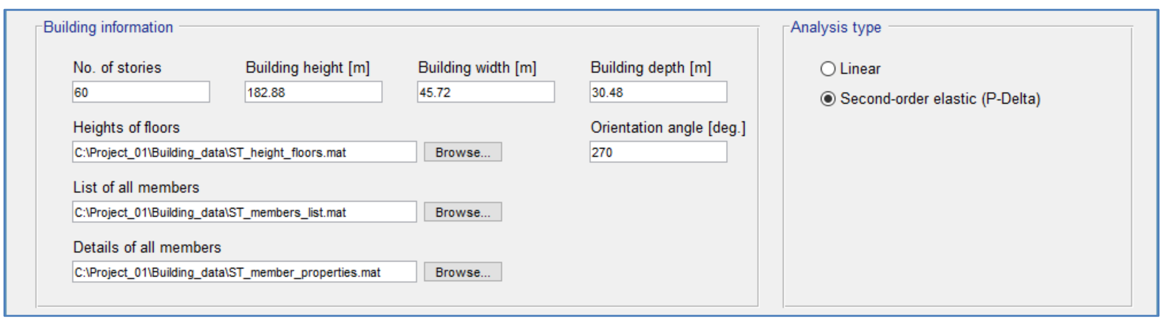


Figure 7. Building information panel

Step 2. Determine the building's structural properties

For the design D_0: determine the building's structural properties, including the modal shapes, natural frequencies of vibration, and damping ratios, as well as the requisite influence coefficients; and develop a lumped-mass model of the structure. *P-Δ* an *P-δ* effects can be accounted for by using, for example, the effective stiffness matrix (Park and Yeo 2018).

Structural properties panel:

a. Set the **No. of modes** to **6**.

b. Set the **Modal damping ratio [%]** to **1.5 1.5 1.5 1.5 1.5 1.5** (Type **1.5** six times, successive values should be separated by an empty space).

c. Click the **Browse** button for **Mass matrix** section. Then select *ST_mass_asc.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

d. Select the **Input analysis results from arbitrary FE software**. If you selected the **Second-order elastic (P-Delta)** option, the **Use OpenSees for calculation** section will not be activated.

e. Click the **Browse** button for **Influence coefficients** section. Then select *ST_dif_all.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

f. Click the **Browse** button for **Internal forces due to dead load** section. Then select *ST_frames_DeadLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

g. Click the **Browse** button for **Internal forces due to super-imposed dead load** section. Then select *ST_frames_SDeadLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

h. Click the **Browse** button for **Internal forces due to live load** section. Then select *ST_frames_LiveLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

i. Click the **Browse** button for **Mode shapes** section. Then select *ST_ModeShapes_pd.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

j. Set the **Modal periods [s]** to **6.473 6.098 6.057 2.091 2.065 2.010** (each value should be separated by an empty space).

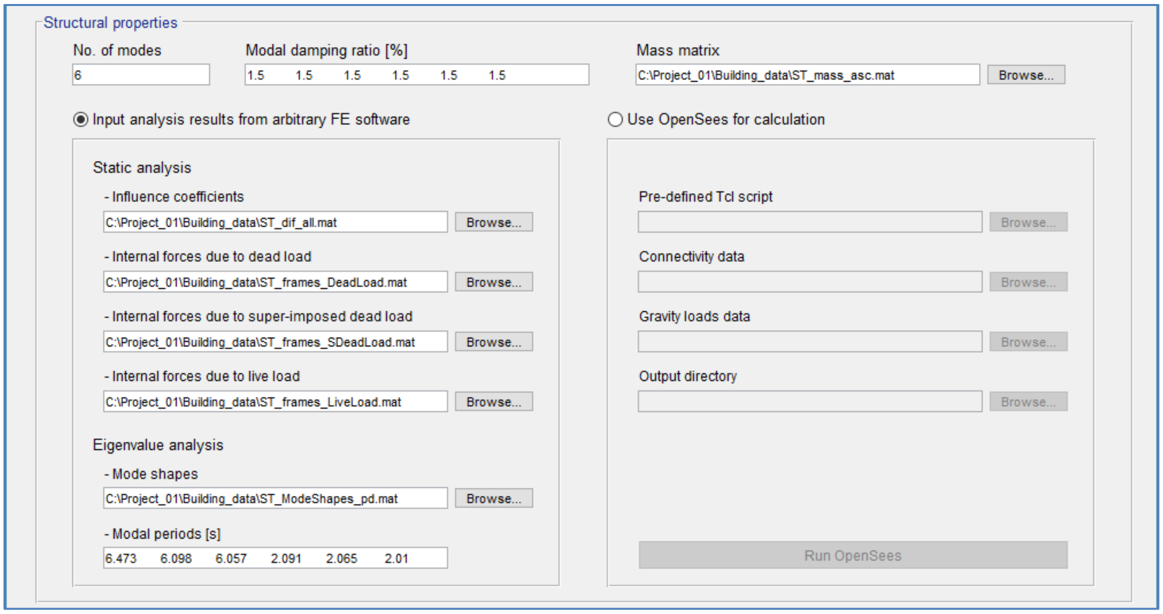


Figure 8. Structural properties panel

k. Move on to the **Wind loads** panel by clicking the **Wind loads** button below.

Step 3. Determine aerodynamic wind loads

From the time histories of simultaneously measured pressure coefficients, determine the time histories of the randomly varying aerodynamic loads induced at all floor levels by mean wind speeds from, depending upon location, 20 m/s to 80 m/s in increments of 10 m/s, say, with directions from $0° \leq \theta_w < 360°$ typically in increments of 10°, say. In this tutorial, we used the wind tunnel data developed at the CRIACIV-DIC Boundary Layer Wind Tunnel (Venanzi 2005).

Wind tunnel test / CWE data panel:

a. Set the **Model length scale [Prototype/Model]** to **500**.

b. Set the **Reference wind speed at rooftop elevation of the building model [m/s]** to **23.2**.

c. Set the **Wind directions [deg.]** to **0:10:360**.

d. Set the **Sampling rate [Hz]** to **250**.

e. Set the **No. of sampling points** [points] to **7504**.

f. Set the **Discarded initial portion of response time series [points]** to **200**.

Move onto the **Floor wind loads at model scale [N and N.m]** section.

h. Select the **Open the floor wind loads**.

i. Click the **Browse** button, and then select the *Aerodynamic_data* folder in the default directory (C:\ Project_01). In this folder, the floor wind load data files, *Fl_XXX.mat* where *XXX* varies from ‘000’ to ‘360’ in increments of 10, must be included.

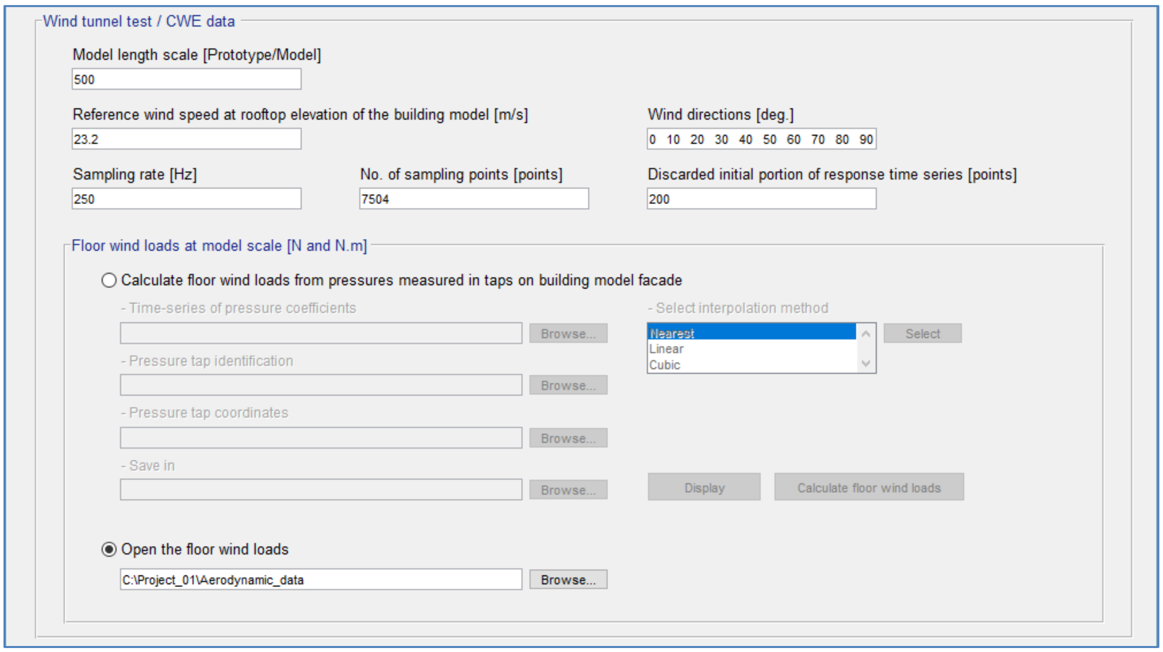


Figure 9. Wind tunnel test / CWE data panel

Wind speed range panel:

a. Set the **Wind speeds for response surfaces [m/s]** to **20:10:80**.

Lower limit requirement panel:

a. Select the **ASCE 7-based overturning moments [N.m]** toggle. Click the **Browse** button and then select *moment_ovtn_ASCE.mat* file from *Building_data* folder in the default directory (C:\Project_01).

b. Click the **80 %** check box on the **Limiting value** section.

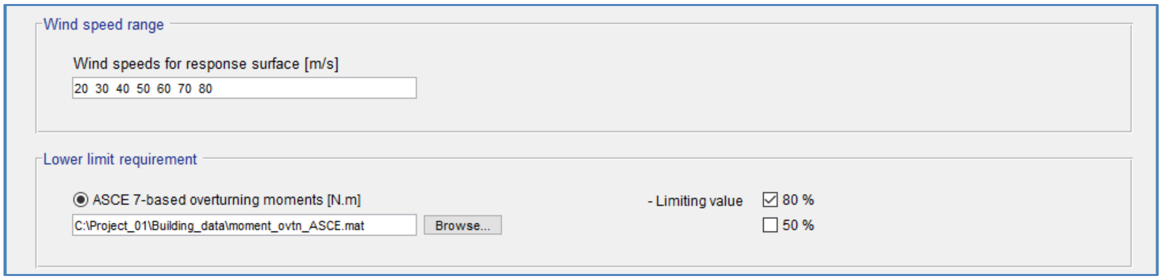


Figure 10. Wind speed range and lower limit requirement panel

c. Move on to the **Resp. surface** panel by clicking the **Resp. surface** button below.

Step 4-6. Perform dynamic analysis and construct response surfaces for wind effects

Perform the dynamic analysis based on the lumped-mass model of the structure to obtain the time histories of the inertial forces induced by the respective aerodynamic loads, and the effective wind-induced loads consisting of the sums of the aerodynamic and inertial force time histories. The lateral loads are determined at all floor levels of the building. Construct the response surfaces of the peak combined effects (e.g., DCIs, inter-story drift ratio, accelerations) as functions of wind speed and direction.

Load combination cases panel:

a. Set the **Dead load (D)** to **1.2**.

b. Set the **Super-imposed dead load (Ds)** to **1.2**.

c. Set the **Live load (L)** to **1**.

d. Click the **Add** button. The list box above the button will display the load combination case LC1 based on the load factors you set. If your inputs are wrong, click the **Reset** button, then the list box will be empty. Re-input the load factors from the step 'a'.

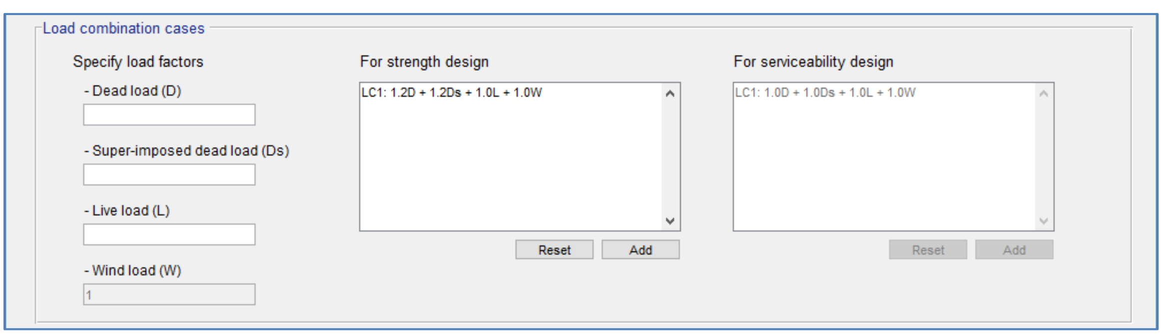


Figure 11. Load combination cases panel

Calculation options panel:

a. Select the **DAD** toggle.

b. Click the **Multiple Points-In-Time approach** check box. Set the points to **30**.

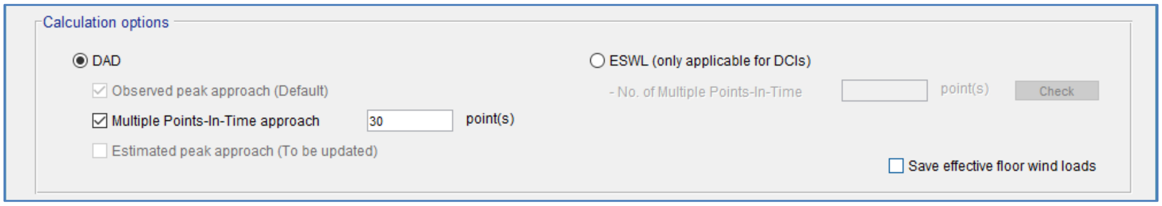


Figure 12. Calculation options panel

Response surface panel:

For the **Demand-to-Capacity Index (DCI)** section,

a. Click the **Browse** button for **Specify members of interest** section. Then select *ST_member_selected_simple.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

Note) The selected members of interest in this example are three columns, member ID = 1, 10, and 20, out of 8140 members.

b. Click the **Browse** button for **Save as** section. Then type **'DCI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_01).

For the **Inter-story drift ratio** section,

c. Click the **Browse** button for **Specify column lines of interest** section. Then select *ST_Interstory_Drift_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

d. Click the **Browse** button for **Save as** section. Then type **'InDr'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_01).

For the **Accelerations** section,

e. Click the **Browse** button for **Specify column lines of interest** section. Then select *ST_Acceleration_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_01).

f. Click the **Browse** button for **Save as** section. Then type **'Acc'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_01).

g. Click the **Compute response surface** button. The pop-up window will then appear to show the progress of the calculation (Fig. 14).

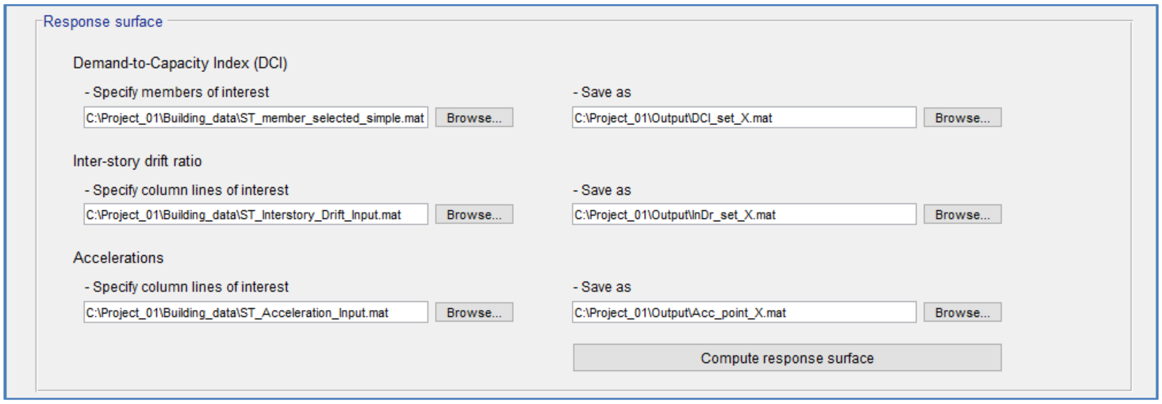


Figure 13. Response surface panel

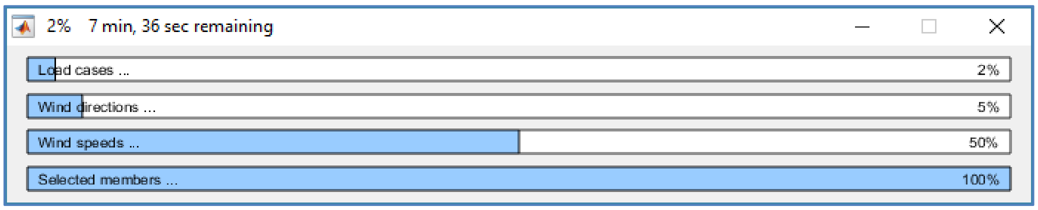


Figure 14. Progress bar

i. Please wait until the calculation is done. This might take several minutes.

j. Once the calculation is done, the progress bar will be automatically disappeared. Then move onto the **Wind effects** panel by clicking the **Wind effects** button below.

Step 7. Determine design wind effects with specified MRIs

Use the information contained in the response surfaces and in the matrices of directional wind speeds at the site to determine, by accounting for wind directionality, the design DCIs with the specified design MRI for the cross sections of interest.

Wind climatological data panel:

a. Select the **Wind climatological data 1** toggle.

b. Click the **Browse** button for **Specify the data file** section. Then select *Nhurr_Miami(182).mat* file from the *Climatological_data_1* directory from the default directory (C:\ Project_01).

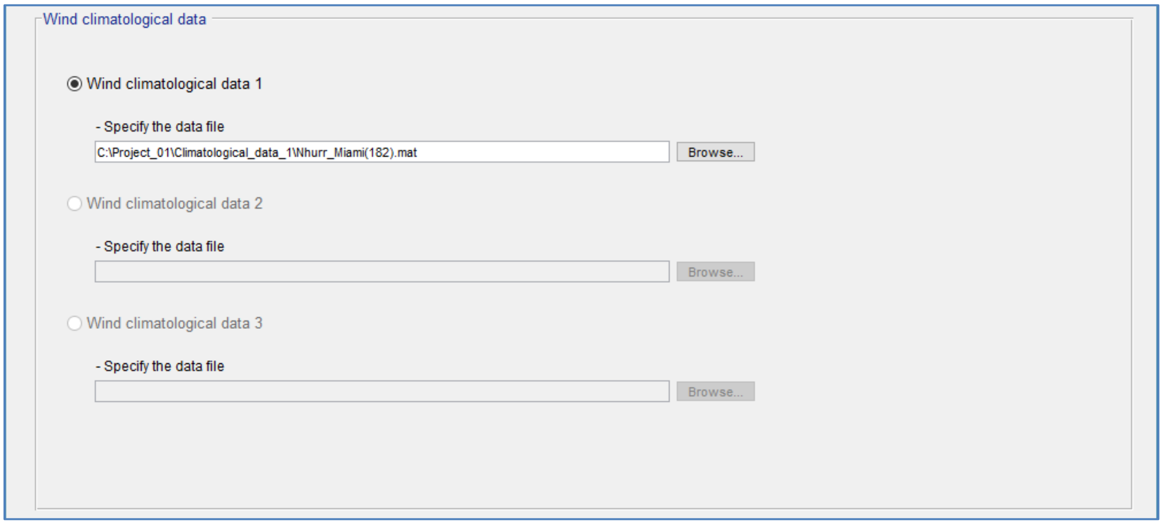


Figure 15. Wind climatological data panel

Design responses for specified MRIs panel:

a. Set the **MRIs for demand-to-capacity index [years]** to **1700**.

b. Click the **Browse** button for **Save as** section. Then type **'DCI_MRI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_01).

c. Set the **MRIs for inter-story drift ratio [years]** to **20**.

d. Click the **Browse** button for **Save as** section. Then type **'InDr_MRI'** as a new filename for inter-story drift results in *Output* folder in the default directory (C:\ Project_01).

e. Set the **MRIs for acceleration [years]** to **10**.

f. Click the **Browse** button for **Save as** section. Then type **'Acc_MRI'** as a new filename for acceleration results in *Output* folder in the default directory (C:\ Project_01).

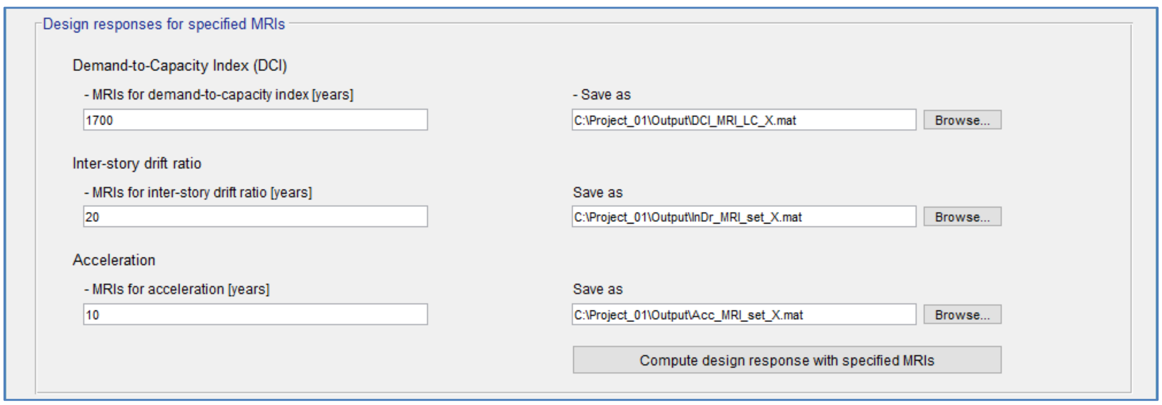


Figure 16. Design responses for specified MRIs panel

g. Click the **Compute design response with specified MRIs** button. The pop-up window will appear to set the number of workers for parallel computing (Fig. 17).

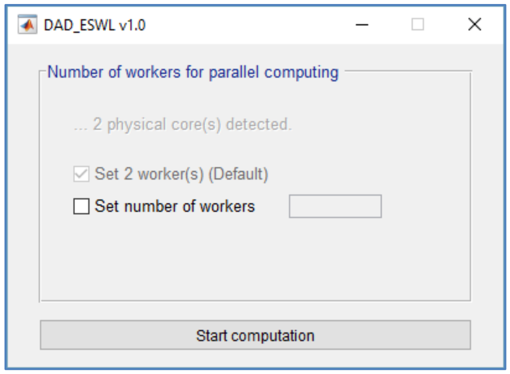


Figure 17. Parallel computing setting dialog

h. After setting the number of workers, click the **Start computation** button. The progress bar will then appear. Please wait until the calculation is done. This might take several minutes.

i. Once the calculation is done, the progress bar will be automatically disappeared. Move onto the **Results & Plots** panel by clicking the **Results & Plot** button below.

3.6 Displaying analysis results for DAD_ESWL

This section provides a tutorial for displaying the analysis results in the software.

Results & Plots panel:

a. Select the **Demand-to-Capacity Index (DCI)** toggle.

b. Select **LC1** from the list box on the **Load case** section. Click the **Check** button.

c. Select **1** from the list box on the **Member** section. Click the **Check** button.

d. Select **1700** from the list box on the **For MRI** section. Click the **Calc** button.

e. Check the values displayed on the boxes below. These values are the peak DCIs with 1700 years-MRI.

f. In the **Plot option** section, click the **DCI^{PM}** toggle to display the response surface for the DCI^{PM} of the selected member.

g. Click the **Plot response surface** button below the figure displaying area. Then check the response surface (Fig. 19).

h. Click the **Plot design response** button below the figure displaying area. Then check the peak DCIs depending upon the MRIs (Fig. 20).

i. If you want to edit the figure currently displayed, e.g., rotating a viewing-angle of the figure, moving the objects of figures like legend and title, or saving the figure to local hard drive of your computer, click the **Edit figure** button.

Note 1. For the other wind effects, i.e., **Overturning moment**, **Inter-story drift ratio**, and **Acceleration**, do the same step from 'a' to 'i'. To see a detailed function for each selection, please refer to the User's Manual in NIST Technical Note 2000.

Note 2. For details about the output files you saved in the default folder, '*Output*', please refer to the User's Manual in NIST Technical Note 2000.

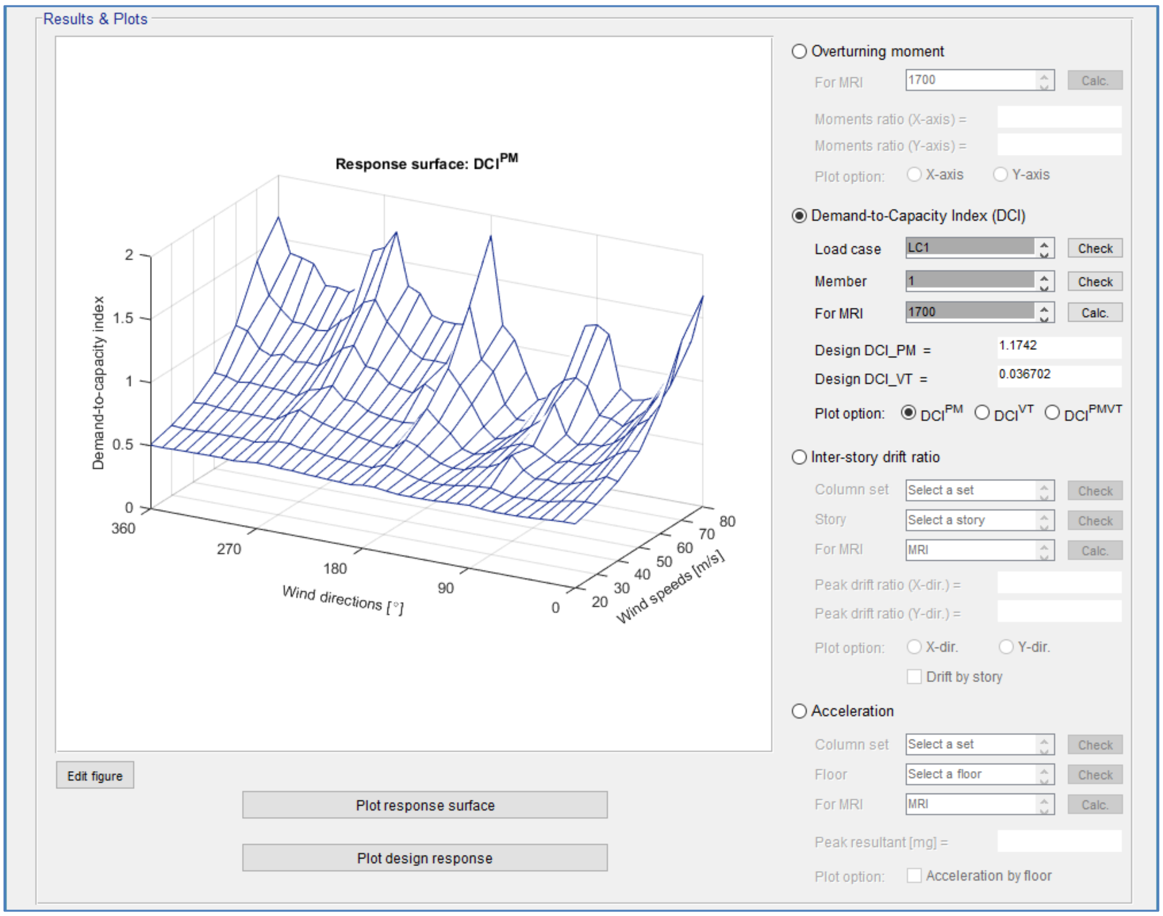


Figure 18. Results & Plots panel: Plot response surface

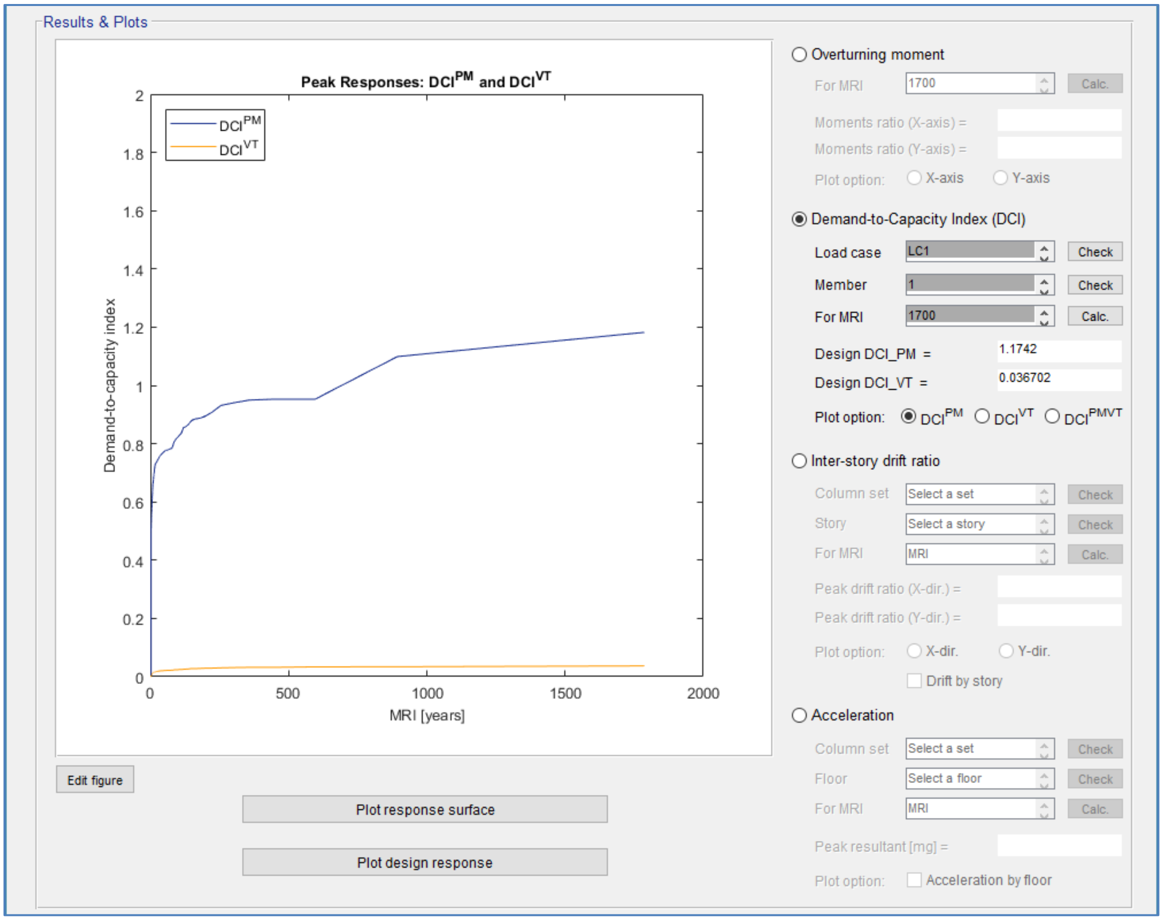


Figure 19. Results & Plots panel: Plot design response

Chapter 4. Example project 2: 60-story steel building II

4.1 Project description

The example project 2 is presented with a view to guiding users on how to work with OpenSees. The 60-story building, which is identical to the example project 1, will be analyzed by implementing the DAD procedure with the use of randomly fluctuating wind loads acting at each floor, which were calculated in advance by the authors from the pressure coefficient data (C_p) obtained in the wind tunnel testing reported by Venanzi (Venanzi 2005).

The example building is a 60-story steel building, known as the CAARC building (Melbourne 1980), with floors assumed to be rigid diaphragms (Fig. 20). The building is 45.72 m in width, 30.48 m in depth, and 182.88 m in height, and has 6-bay by 4-bay. It has an outrigger and belt truss system located on 20th, 21st, 40th, 41st, and 60th story, and consists of 2100 columns, 3480 beams, and 2560 diagonal bracings. The building is assumed to have suburban exposure near Newark, New Jersey. Large hurricane and non-hurricane climatological databases for estimation of wind effects with long MRIs under mixed wind climates are applied to this project. The orientation angle of the building is 270° clockwise from the north, that is, a front façade of the building faces north. Second-order effects will not be accounted for. The building will be analyzed for gravity and aerodynamic loads with the load combination $1.2D + 1.0L + 1.0W$ (denoted by LC1), where D is the total dead load, L is the live load, and W is the wind load.

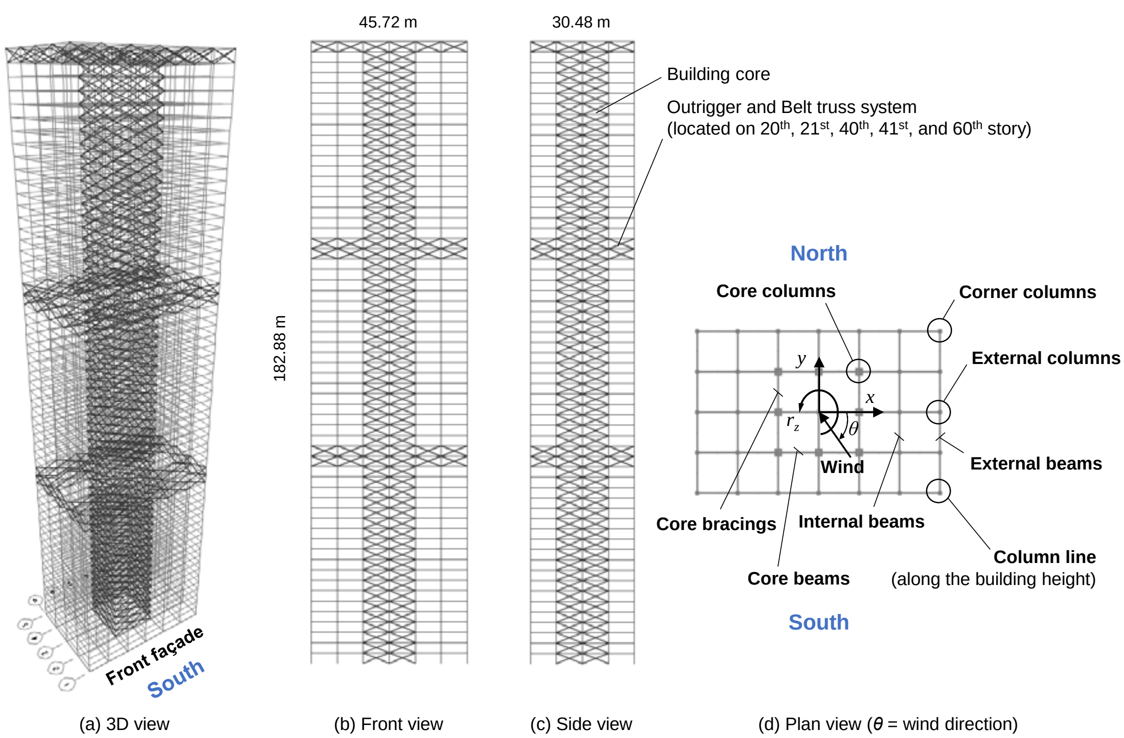


Figure 20. 60-story steel building model II

OpenSees for static and modal analyses is adopted to obtain the influence coefficients, internal forces of members, and modal properties. The users can reduce the effort of converting those building's structural data to make it available to the *DAD_ESWL* by using OpenSees. This process is performed internally in the *DAD_ESWL*.

Make sure that the '*OpenSees*' folder contains the executable file of OpenSees (OpenSees.exe), the user's pre-defined Tcl file and other inputs related to use the OpenSees. The OpenSees interpreter, Tcl/Tk language is used to define the geometry of the model, loading, formulation, and solution. The Tcl is a string-based scripting language, and more information on Tcl commands can be found at: http://tcl.tk/doc/.

To run the project, download a folder named '*Project_02*' from the website http://nist.gov/wind and save it on your local drive C shown in Fig 21.

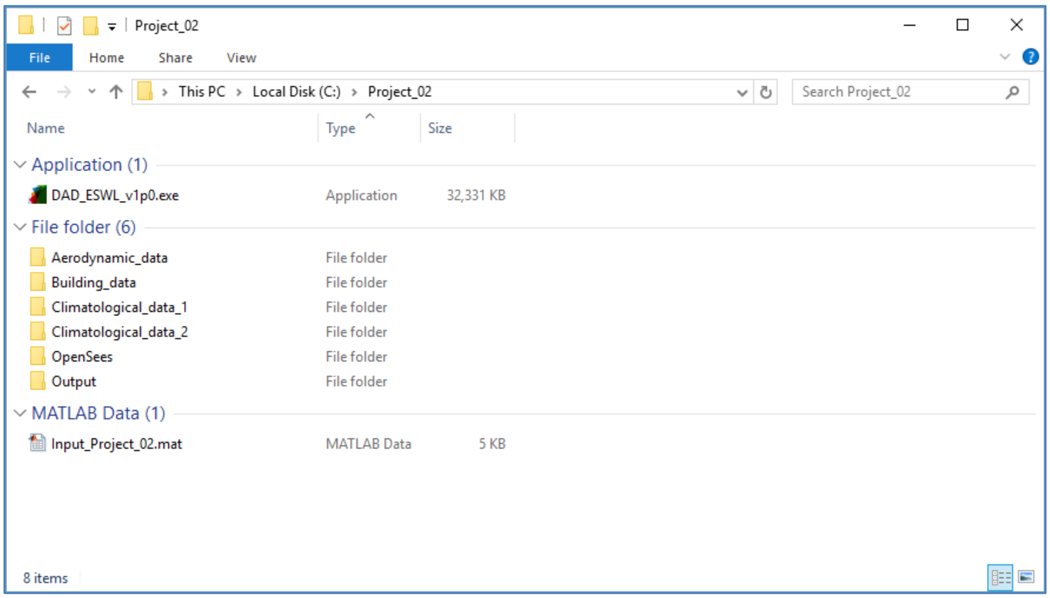


Figure 21. Directory structure for example project 2

Note that the '*Input_Project_02.mat*' file is not the mandatory file for running the software. However, this file is provided for the convenience of the users. It contains all the input values and file path values needed for the example project 2. The users can use this file through the 'Open inputs' button in the software.

4.2 Structural data

All the members' cross-sectional dimensions for the preliminary design, D_0, are listed in Table 4. *DAD_ESWL* requires additional sectional properties based on those dimensions, e.g., area, torsional constant, moment of inertia, shear area, and radius of gyration (see the User's Manual in NIST Technical Note 2000 for details).

After obtaining initial dimensions of the structural members, the Tcl script for running OpenSees, elements' connectivity data, and applied gravity loads should be made. The mandatory structural data, i.e., influence coefficients, internal forces induced by gravity loads of the members, natural periods of vibration, and mode shapes, will then be calculated by static and modal analyses in OpenSees. The modal damping ratios are assumed to be 1.5 % in all six modes considered in this project.

The building's structural data, pre-defined Tcl script, and additional files are included in '*Building_data*' and '*OpenSees*' folder. Table 5 lists the structural data required to analyze this example project, and their file name and path.

Table 4. Members' cross-section dimensions (unit = mm)

Members' type	Section ID	Sectional type	Depth	Width	Flange thickness	Web thickness
Bracing	1	Box/Tube	500	30	15	15
	2	Box/Tube	400	30	15	15
	3	Box/Tube	300	25	12	12
Column	1	Box/Tube	700	700	50	50
	2	Box/Tube	600	600	50	50
	3	Box/Tube	600	600	40	40
	4	Box/Tube	600	600	30	30
	5	Box/Tube	500	500	20	20
	6	Box/Tube	400	400	15	15
	7	Box/Tube	1400	1400	50	50
	8	Box/Tube	1200	1200	50	50
	9	Box/Tube	1000	1000	50	50
	10	Box/Tube	800	800	40	40
	11	Box/Tube	600	600	30	30
	12	Box/Tube	400	400	20	20
Beam	1	I/Wide Flange	253.49	254.00	14.22	8.64

Table 5. Building's structural data

Structural data	File name	Path
Members' list	*ST_members_list.mat*	
Members' properties	*ST_member_properties.mat*	C:\Project_02\Building_data
Mass matrix	*ST_mass_asc.mat*	
Tcl script	*ST_Frame3D_predefined.tcl*	
Elements' connectivity	*model_props.mat*	C:\Project_02\OpenSees
Applied gravity loads	*gravity_loads.mat*	

4.3 Aerodynamic data

The example building is assumed to have suburban terrain exposure. Time series of aerodynamic loads on each floor are calculated from the pressure data induced by wind velocities with wind directions in 10° increments (0°, 10°, …, 350°). The pressure coefficients were measured in wind tunnel tests at the Prato (Italy) Inter-University Research Centre on Building Aerodynamics and Wind Engineering (CRIAC IV-DIC) Boundary Layer Wind Tunnel (Venanzi 2005).

The length scale of the aerodynamic model was 1:500. The duration of the records was 30 s with sampling frequency of 250 Hz for a total approximately 7500 samples for each pressure tap. The mean wind speed at top of the building model during the wind tunnel tests was 23.2 m/s. Since a numerical integration needs a certain number of points before it stabilizes, the first 200 points of the time series are not used in the DAD analysis.

The floor wind load data (*Fl_XXX.mat*, where *XXX* varies from '000' to '360' by in increments of 10) are included in '*Aerodynamic_data*' folder.

4.4 Climatological data

This project requires large hurricane and non-hurricane climatological databases for estimation of wind effects with long MRIs under mixed wind climates. The hurricane database generated in this project consists of synthetic directional wind speeds in 16 directions for 999 storm events near Newark, New Jersey (Milepost 2500). The non-hurricane (i.e., in this project, thunderstorm) database generated in this project consists of synthetic directional wind speeds in 36 directions for 79389 events. Details on the generation of synthetic wind speed data are provided in Yeo (2014). Terrain exposures at weather station where the hurricane winds were measured and at the location of the building are open (category 'C') and suburban (category 'B'), respectively. The orientation angle of the example building is 270° clockwise from the north, that is, the front façade of the building faces north.

Peak responses are obtained for the DCIs corresponding to a 1700-year MRI. Peak inter-story drifts and accelerations of the building will be obtained from the peak response surfaces for MRI = 20 years and MRI = 10 years, respectively.

The hurricane wind speed dataset (*Nhurr_Newark(182).mat* file for the milepost 2500) and the non-hurricane wind speed dataset (*TS_Newark(182).mat* file) are included in '*Climatological_data_1*' and in '*Climatological_data_2*' directories.

4.5 Step-by-step tutorial for DAD_ESWL

This section provides step-by-step tutorial for the use of *DAD_ESWL* software to analyze the example building subjected to wind. The tutorial follows the seven tasks (steps) of the DAD procedure shown in Fig. 1.

Step 1. Begin a new model with preliminary design D_0

Select the structural system, and determine its preliminary member sizes by using a simplified model of the wind loading (e.g., a static wind loading based on standard provisions). The structural design so achieved is denoted by D_0.

Select the structural system

a. Run **DAD_ESWL_v1p0.exe**, select the **Steel Structure,** and click the **Start** button.

Note. Please wait until the initial page is open. It might take several minutes.

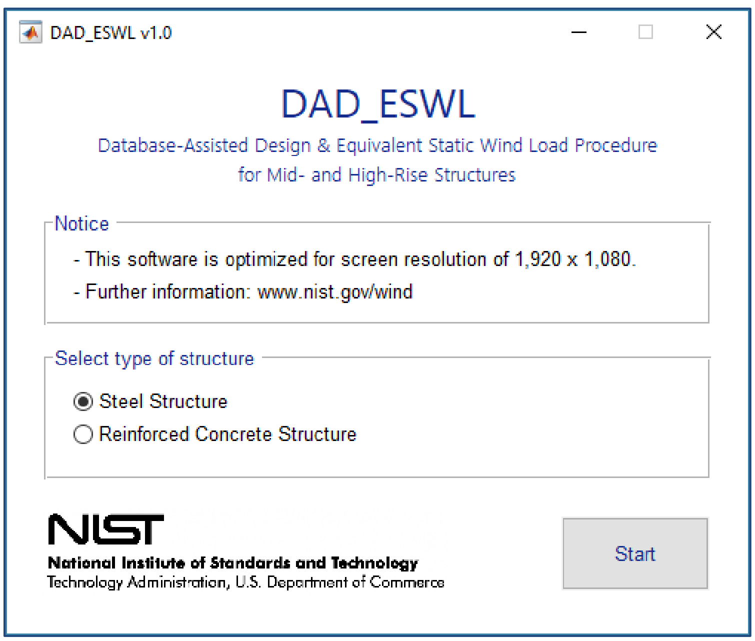


Figure 22. Structural type selection panel

The software will then display the main GUI of the **Bldg. modeling** input panel.

Building information panel and Analysis type panels:

a. Set the **No. of stories** to **60**.

b. Set the **Building height [m]** to **182.88**.

c. Set the **Building width [m]** to **45.72**.

d. Set the **Building depth [m]** to **30.48**.

e. Set the **Orientation angle [deg.]** to **270**.

f. Click the **Browse** button for **Heights of floors** section. Then select *ST_height_floors.mat* file from *Building_data* folder in the default directory (C:\ Project_02).

g. Click the **Browse** button for **List of all members** section. Then select *ST_members_list.mat* file from *Building_data* folder in the default directory (C:\ Project_02).

h. Click the **Browse** button for **Details of all members** section. Then select *ST_member_properties.mat* file from *Building_data* folder in the default directory (C:\ Project_02).

i. Go to the **Analysis type** section on the right side. The **Linear** toggle may stay on as a default. If not, select the **Linear** toggle.

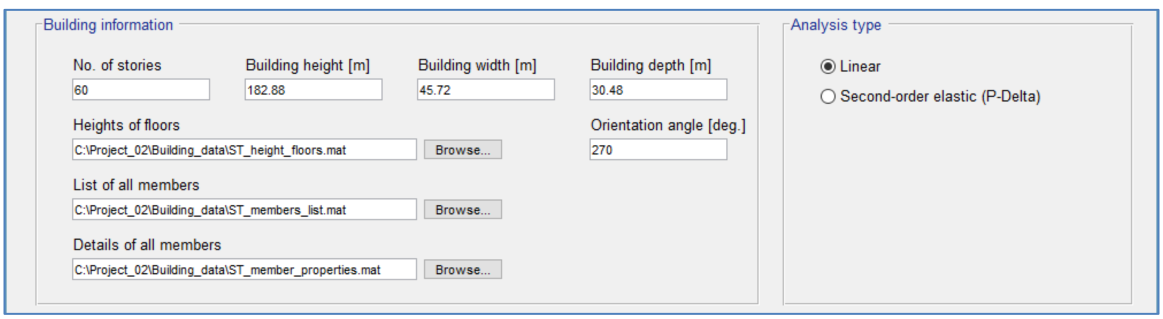


Figure 23. Building information panel

Step 2. Determine the building's structural properties

For the design D_0: determine the building's structural properties, including the modal shapes, natural frequencies of vibration, and damping ratios, as well as the requisite influence coefficients; and develop a lumped-mass model of the structure. $P\text{-}\Delta$ an $P\text{-}\delta$ effects can be accounted for by using, for example, the effective stiffness matrix (Park and Yeo 2018).

Structural properties panel:

a. Set the **No. of modes** to **6**.

b. Set the **Modal damping ratio [%]** to **1.5 1.5 1.5 1.5 1.5 1.5** (Type **1.5** six times, successive values should be separated by an empty space).

c. Click the **Browse** button for **Mass matrix** section. Then select *ST_mass_asc.mat* file from *Building_data* folder in the default directory (C:\ Project_02).

d. Select the **Use OpenSees for calculation** toggle.

e. Click the **Browse** button for **Pre-defined Tcl script** section. Then select *ST_Frame3D_predefined.tcl* file from *OpenSees* folder in the default directory (C:\ Project_02).

f. Click the **Browse** button for **Connectivity data** section. Then select *model_props.mat* file from *OpenSees* folder in the default directory (C:\ Project_02).

g. Click the **Browse** button for **Gravity loads data** section. Then select *gravity_loads.mat* file from *OpenSees* folder in the default directory (C:\ Project_02).

h. Click the **Browse** button for **Output directory** section. Then select *OpenSees* folder in the default directory (C:\ Project_02).

i. Click the Run OpenSees button. The pop-up window will then appear to show the progress of the analysis (Fig. 26).

j. Click the **Make required matrices** button located in the right upper of the window (red circles on Fig. 26). The pop-up window will then appear to show the progress of the calculation (Fig. 27).

k. After all these calculations, the *DAD_ESWL* displays a dialog window as shown below (Fig. 28). The **Close all** button close the pop-up window showing the progress and results and the dialog window.

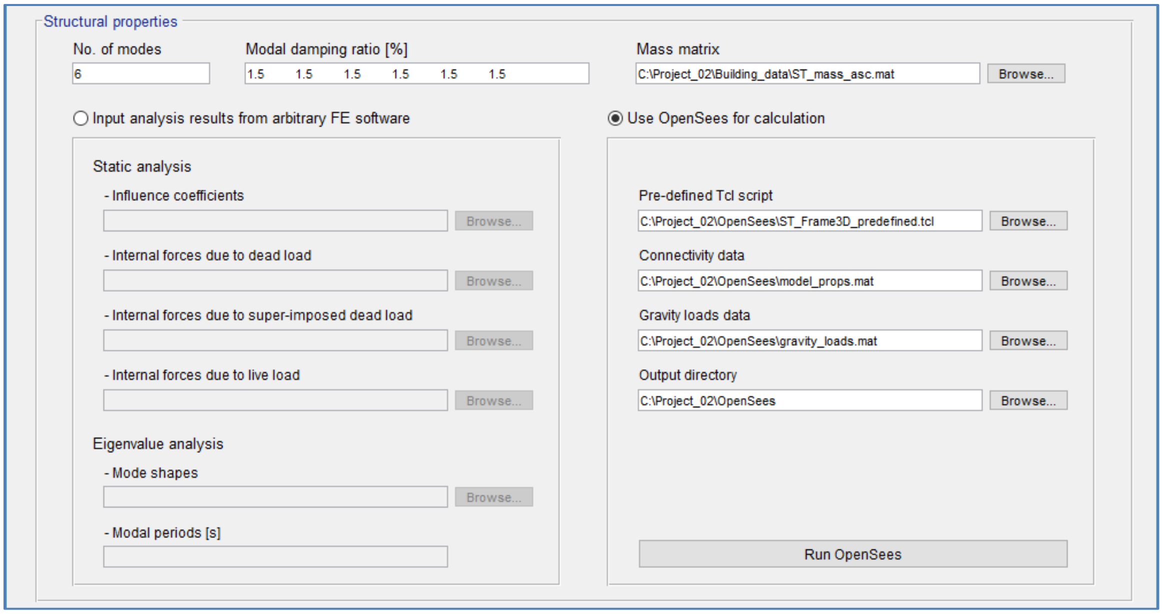


Figure 24. Structural properties panel

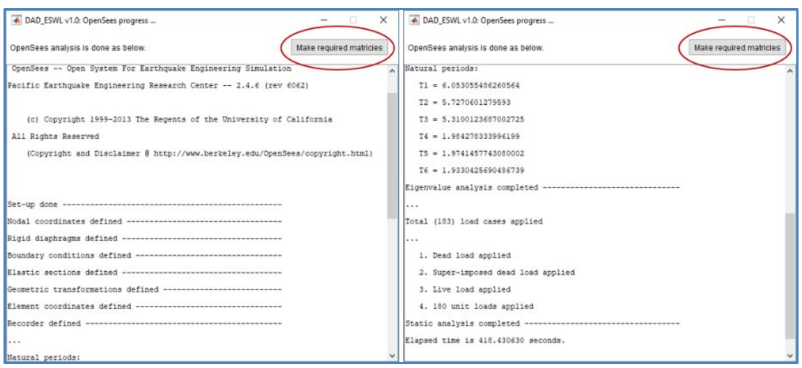


Figure 25. OpenSees progress window

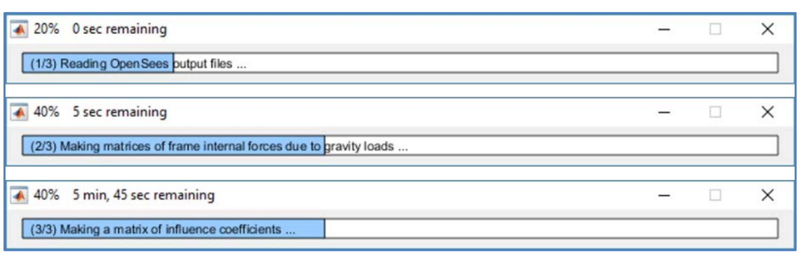


Figure 26. Progress bars

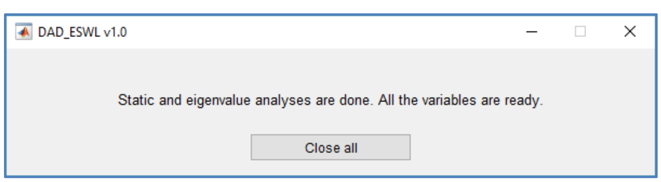


Figure 27. OpenSees dialog

l. Move onto the **Wind loads** panel by clicking the **Wind loads** button below.

Step 3. Determine aerodynamic wind loads

From the time histories of simultaneously measured pressure coefficients, determine the time histories of the randomly varying aerodynamic loads induced at all floor levels by mean wind speeds from, depending upon location, 10 m/s to 80 m/s in increments of 10 m/s, say, with directions from $0° \leq \theta < 360°$ typically in increments of 10°, say. In this tutorial, we used the wind tunnel data developed at the CRIACIV-DIC Boundary Layer Wind Tunnel (Venanzi 2005).

Wind tunnel test / CWE data panel:

a. Set the **Model length scale [Prototype/Model]** to **500**.

b. Set the **Reference wind speed at rooftop elevation of the building model [m/s]** to **23.2**.

c. Set the **Wind directions [deg.]** to **0:10:360**.

d. Set the **Sampling rate [Hz]** to **250**.

e. Set the **No. of sampling points [points]** to **7504**.

f. Set the **Discarded initial portion of response time series [points]** to **200**.

Move onto the **Floor wind loads at model scale [N and N.m]** section.

g. Select the **Open the floor wind loads**.

h. Click the **Browse** button, and then select *Fl_000.mat* file from *Aerodynamic_data* folder in the default directory (C:\ Project_02). In this folder, the floor wind load data files, *Fl_XXX.mat* where *XXX* varies from '000' to '360' in increments of 10, must be included.

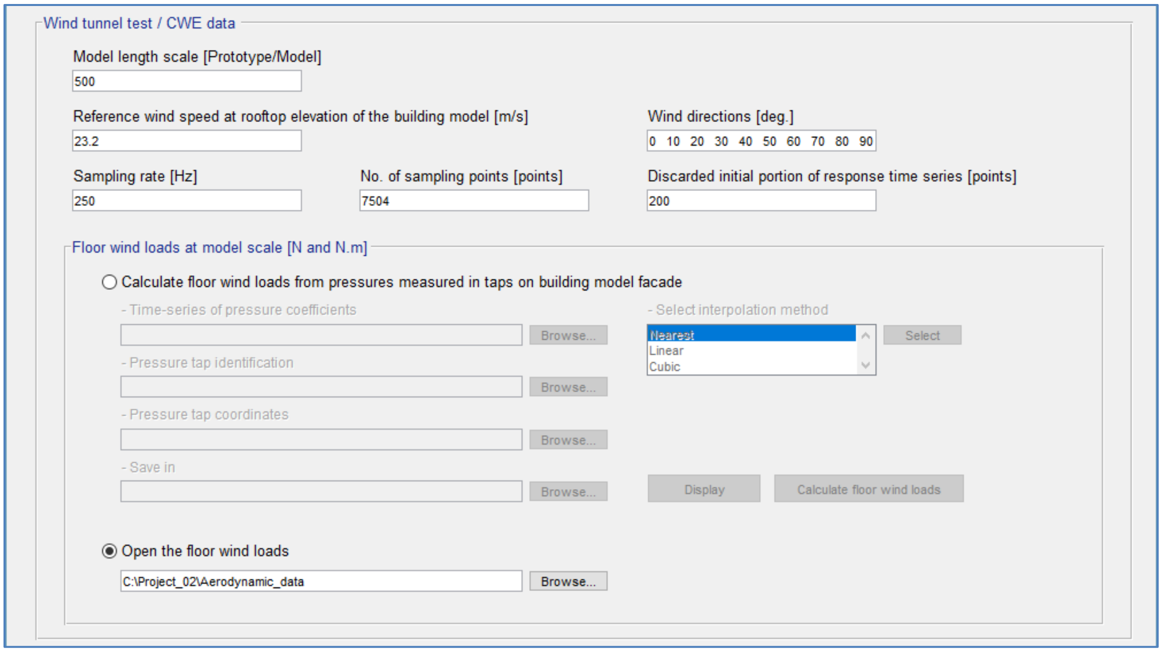


Figure 28. Wind tunnel test / CWE data panel

Wind speed range panel:

a. Set the **Wind speeds for response surfaces [m/s]** to **20:10:80**.

Lower limit requirement panel:

a. Select the **ASCE 7-based overturning moments [N.m]** toggle. Click the **Browse** button and then select *moment_ovtn_ASCE.mat* file from *Building_data* folder in the default directory (C:\Project_02).

b. Click the **80 %** check box on the **Limiting value** section.

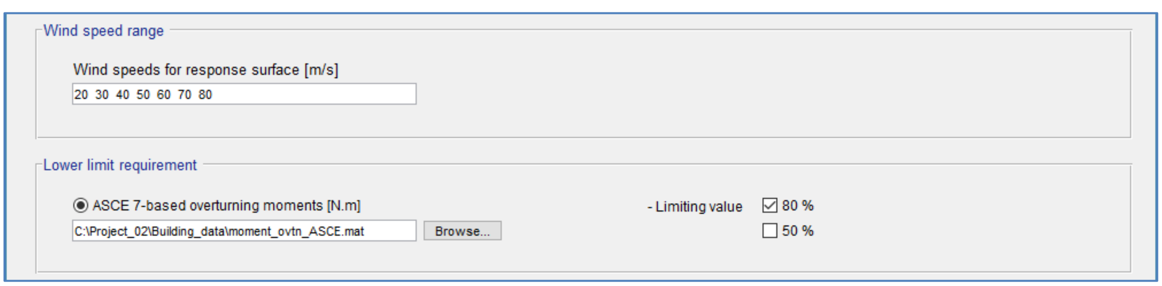


Figure 29. Wind speed range and lower limit requirement panel

c. Move on to the **Resp. surface** panel by clicking the **Resp. surface** button below.

Step 4-6. Perform dynamic analysis and construct response surfaces for wind effects

Perform the dynamic analysis based on the lumped-mass model of the structure to obtain the time histories of the inertial forces induced by the respective aerodynamic loads, and the effective wind-induced loads consisting of the sums of the aerodynamic and inertial force time histories. The lateral loads are determined at all floor levels of the building. Construct the response surfaces of the peak combined effects (e.g., DCIs, inter-story drift ratio, accelerations) as functions of wind speed and direction.

Load combination cases panel:

a. Set the **Dead load (D)** to **1.2**.

b. Set the **Super-imposed dead load (Ds)** to **1.2**.

c. Set the **Live load (L)** to **1**.

d. Click the **Add** button. The list box above the button will display the load combination case LC1 based on the load factors you set. If your inputs are wrong, click the **Reset** button, then the list box will be empty.

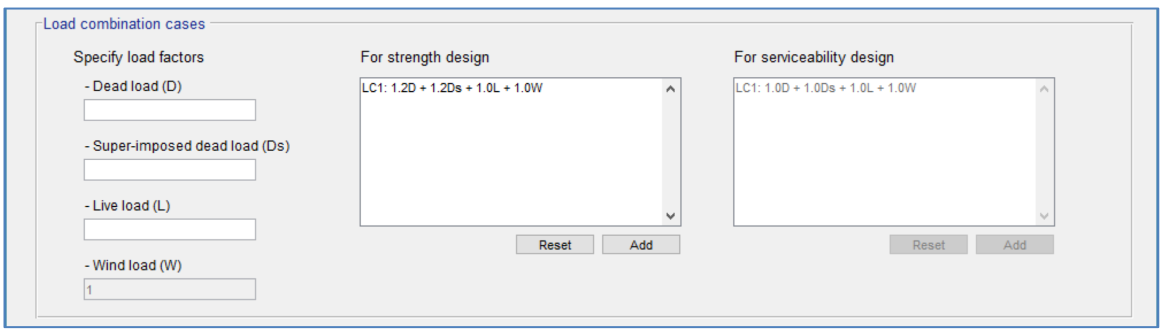


Figure 30. Load combination cases panel

Calculation options panel:

a. Select the **DAD** toggle.

b. Click the **Multiple Points-In-Time approach** check box. Set the points to **30**.

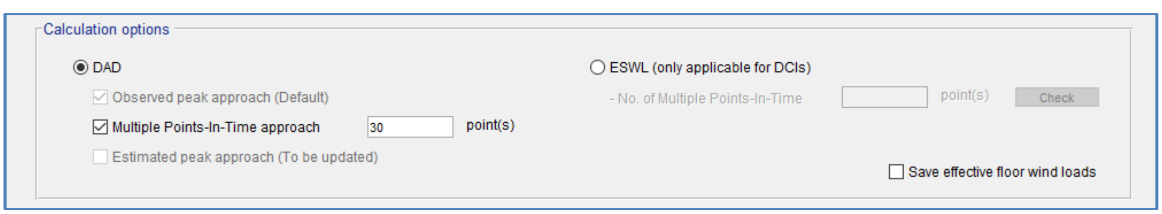


Figure 31. Calculation options panel

Response surface panel:

For the **Demand-to-Capacity Index (DCI)** section,

a. Click the **Browse** button for **Specify members of interest** section. Then select *ST_member_selected_simple.mat* file from *Building_data* folder in the default directory (C:\ Project_02).

Note) The selected members of interest in this example are three columns, member ID = 1, 10, and 20, out of 8140 members.

b. Click the **Browse** button for **Save as** section. Then type **'DCI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_02).

For the **Inter-story drift ratio** section,

c. Click the **Browse** button for **Specify column lines of interest** section. Then select *ST_Interstory_Drift_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_02).

d. Click the **Browse** button for **Save as** section. Then type **'InDr'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_02).

For the **Accelerations** section,

e. Click the **Browse** button for **Specify column lines of interest** section. Then select *ST_Acceleration_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_02).

f. Click the **Browse** button for **Save as** section. Then type **'Acc'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_02).

g. Click the **Compute response surface** button. The pop-up window will then appear to show the progress of the calculation (Fig. 34).

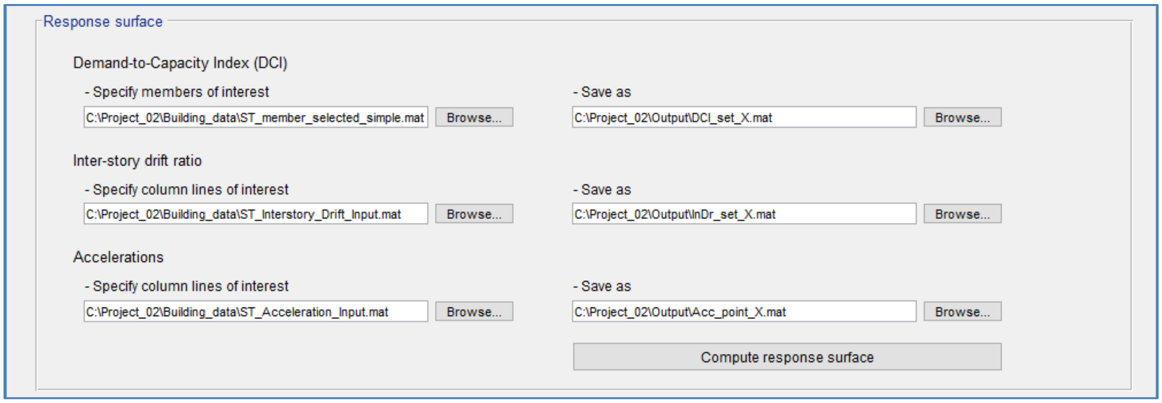


Figure 32. Response surface panel

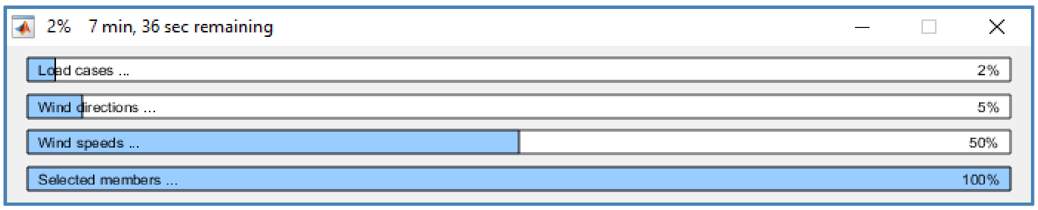


Figure 33. Progress bar

i. Please wait until the calculation is done. This might take several minutes.

j. Once the calculation is done, the progress bar will be automatically disappeared. Then move onto the **Wind effects** panel by clicking the **Wind effects** button below.

Step 7. Determine design wind effects with specified MRIs

Use the information contained in the response surfaces and in the matrices of directional wind speeds at the site to determine, by accounting for wind directionality, the design DCIs with the specified design MRI for the cross sections of interest.

Wind climatological data panel:

a. Select the **Wind climatological data 1** toggle.

b. Click the **Browse** button for **Specify the data file** section. Then select *Nhurr_Newark(182).mat* file from the *Climatological_data_1* directory from the default directory (C:\ Project_01).

c. Select the **Wind climatological data** 2 toggle.

d. Click the **Browse** button for **Specify the data file** section. Then select *TS_Newark(182).mat* file from the *Climatological_data_2* directory from the default directory (C:\ Project_01).

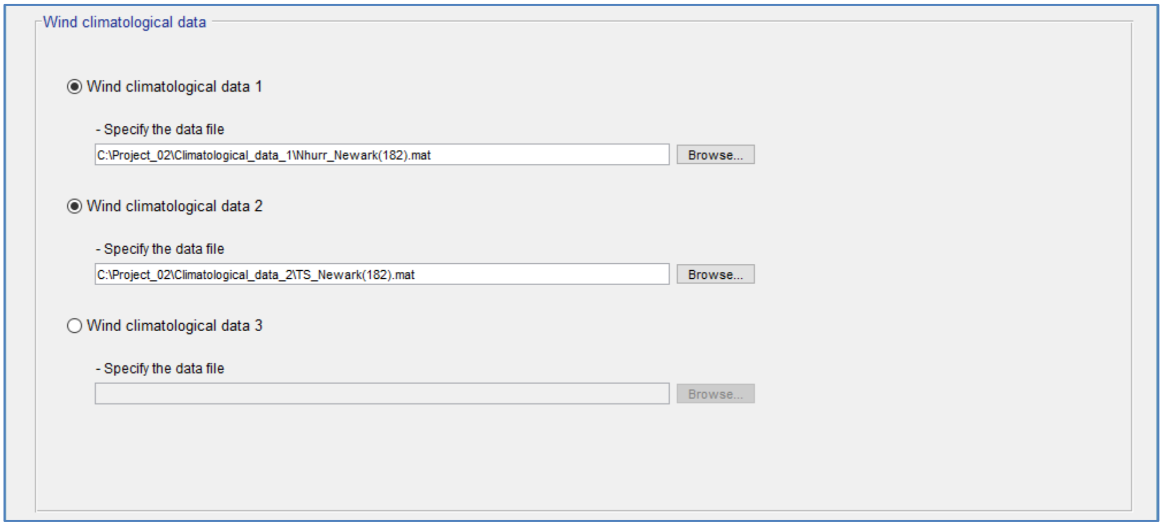


Figure 34. Wind climatological data panel

Design responses for specified MRIs panel:

a. Set the **MRIs for demand-to-capacity index [years]** to **1700**.

b. Click the **Browse** button for **Save as** section. Then type **'DCI_MRI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_02).

c. Set the **MRIs for inter-story drift ratio [years]** to **20**.

d. Click the **Browse** button for **Save as** section. Then type **'InDr_MRI'** as a new filename for inter-story drift results in *Output* folder in the default directory (C:\ Project_02).

e. Set the **MRIs for acceleration [years]** to **10**.

f. Click the **Browse** button for **Save as** section. Then type **'Acc_MRI'** as a new filename for acceleration results in *Output* folder in the default directory (C:\ Project_02).

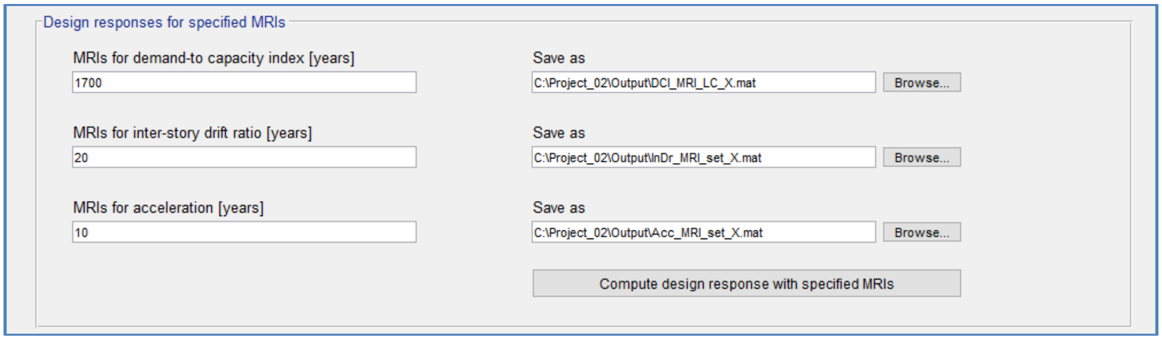


Figure 35. Design responses for specified MRIs panel

g. Click the **Compute design response with specified MRIs** button. The pop-up window will appear to set the number of workers for parallel computing (Fig. 36).

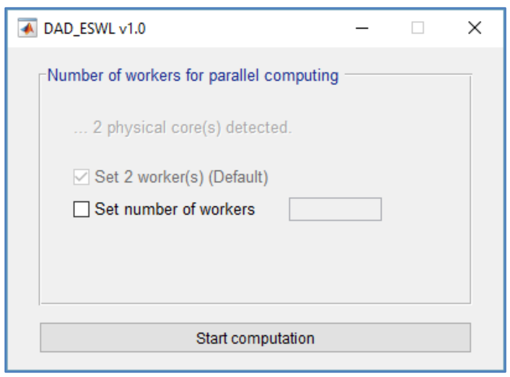


Figure 36. Parallel computing setting dialog

h. After setting the number of workers, click the **Start computation** button. The progress bar will then appear. Please wait until the calculation is done. This might take several minutes.

i. Once the calculation is done, the progress bar will be automatically disappeared. Move onto the **Results & Plots** panel by clicking the **Results & Plot** button below.

4.6 Displaying analysis results for DAD_ESWL

This section provides a tutorial for displaying the analysis results in the software.

Results & Plots panel:

a. Select the **Demand-to-Capacity Index (DCI)** toggle.

b. Select **LC1** from the list box on the **Load case** section. Click the **Check** button.

c. Select **1** from the list box on the **Member** section. Click the **Check** button.

d. Select **1700** from the list box on the **For MRI** section. Click the **Calc** button.

e. Check the values displayed on the boxes below. These values are the peak DCIs with 1700 years-MRI.

f. In the **Plot option** section, click the **DCI^{PM}** toggle to display the response surface for the DCI^{PM} of the selected member.

g. Click the **Plot response surface** button below the figure displaying area. Then check the response surface (Fig. 39).

h. Click the **Plot design response** button below the figure displaying area. Then check the peak DCIs depending upon the MRIs (Fig. 40).

i. If you want to edit the figure currently displayed, e.g., rotating a viewing-angle of the figure, moving the objects of figures like legend and title, or saving the figure to local hard drive of your computer, click the **Edit figure** button.

Note 1. For the other wind effects, i.e., **Overturning moment**, **Inter-story drift ratio**, and **Acceleration**, do the same step from 'a' to 'i'. To see a detailed function for each selection, please refer to the User's Manual in NIST Technical Note 2000.

Note 2. For details about the output files you saved in the default folder, '*Output*', please refer to NIST the User's Manual in Technical Note 2000.

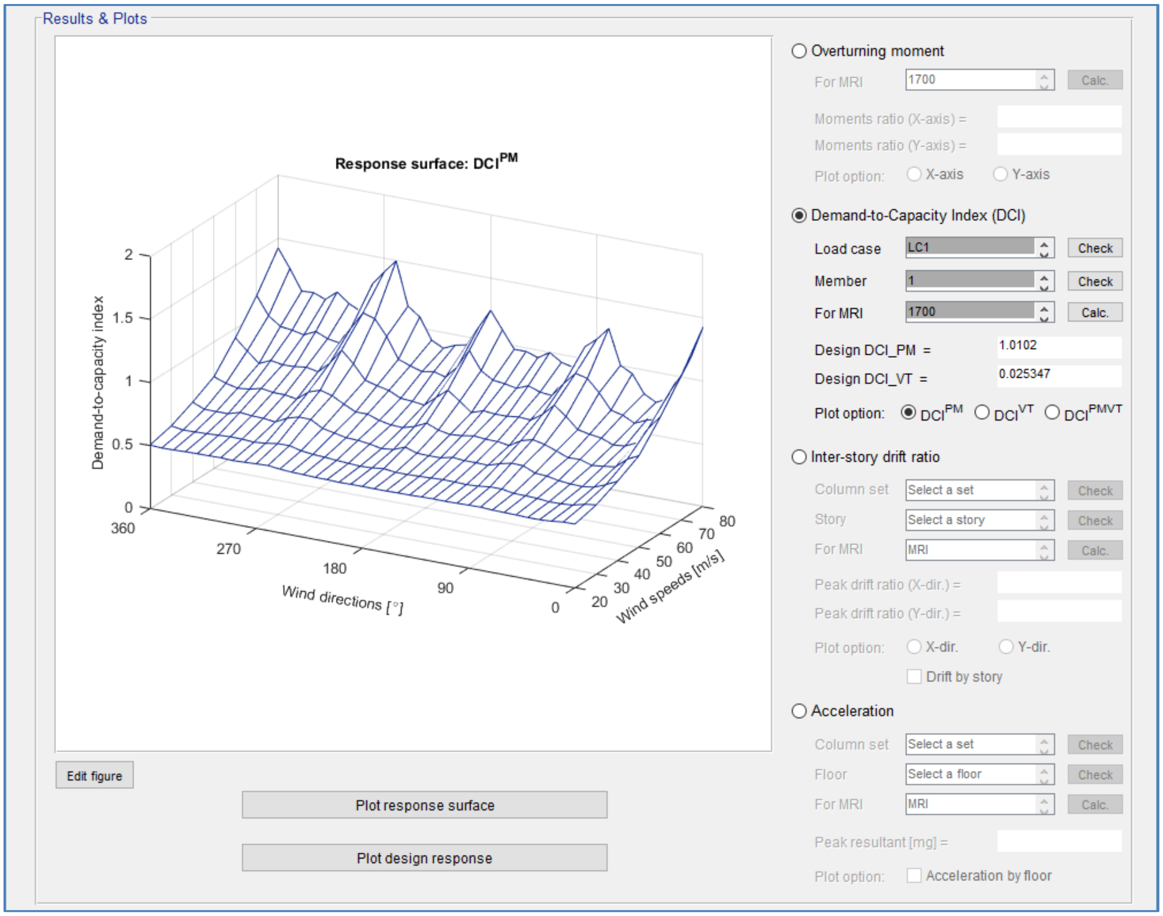


Figure 37. Results & Plots panel: Plot response surface

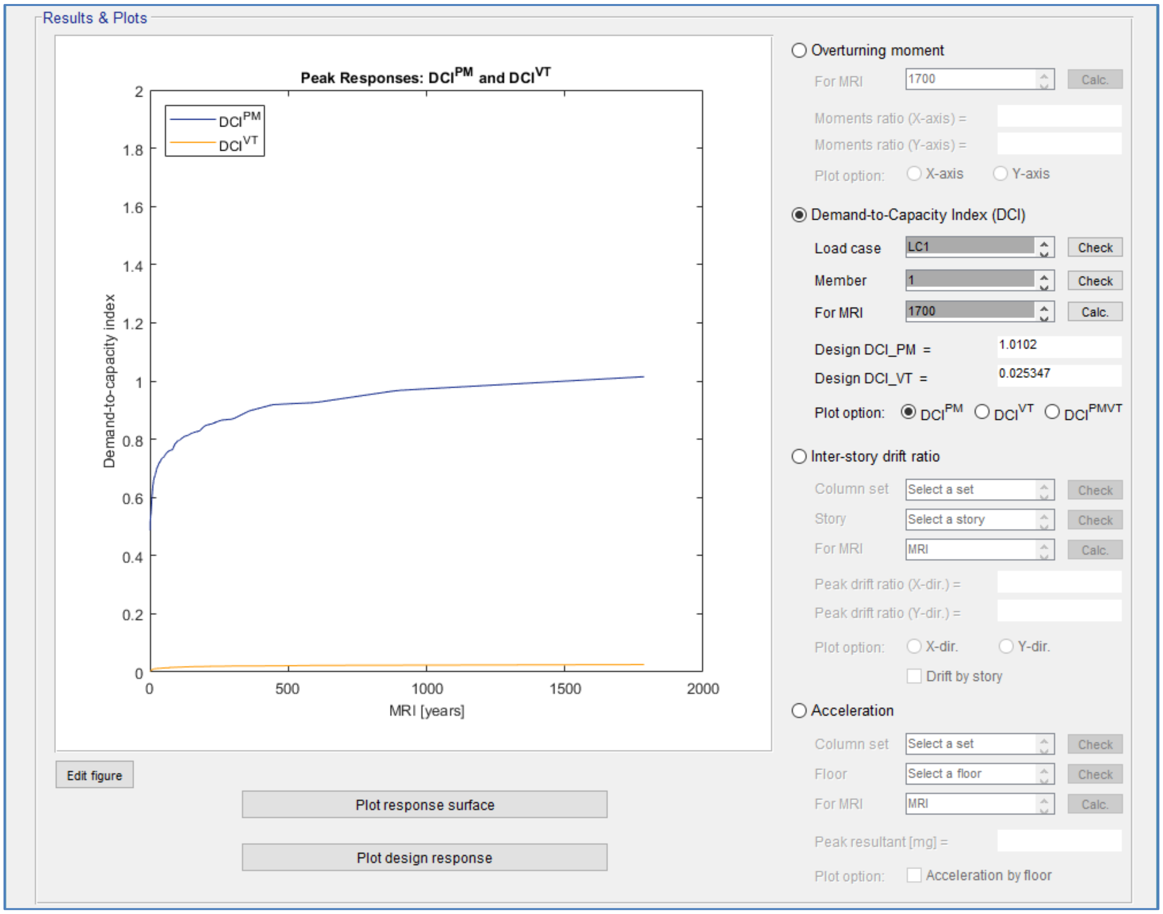


Figure 38. Results & Plot panel: Plot design response

Chapter 5. Example project 3: 60-story RC building

5.1 Project description

The example project 3 is a 60-story reinforced concrete building, known as the CAARC building (Melbourne 1980), with floors assumed to be rigid diaphragms (Fig. 39). The building is 45.72 m in width, 30.48 m in depth, and 182.88 m in height, and its structure consists of 7 bays by 5 bays along the width and the depth, respectively. The structure has a moment-resisting system and contains 2880 columns, 4920 beams. The building is assumed to be located on the suburban terrain near Kansas City, Missouri. The orientation angle of the building is 270° clockwise from the north, that is, the front façade of the building faces north.

The building will be analyzed by implementing the DAD procedure with the use of randomly fluctuating wind loads acting at each floor, which were calculated in advance by the authors from the pressure coefficient data (C_p) obtained in the wind tunnel testing performed by Venanzi (2005). Large non-hurricane climatological databases for estimation of wind effects with long MRIs are applied to this project. The multiple points-in-time approach with 30 points will be applied for calculation. Second-order effects, i.e., P-Δ and P-δ effects, will be accounted for. The building will be analyzed for gravity and aerodynamic loads with the load combination $1.2D + 1.0L + 1.0W$ (denoted by LC1), where D is the total dead load, L is the live load, and W is the wind load.

To run the project, download a folder named '*Project_03*' from the website http://nist.gov/wind and save it on your local drive C shown in Fig 40.

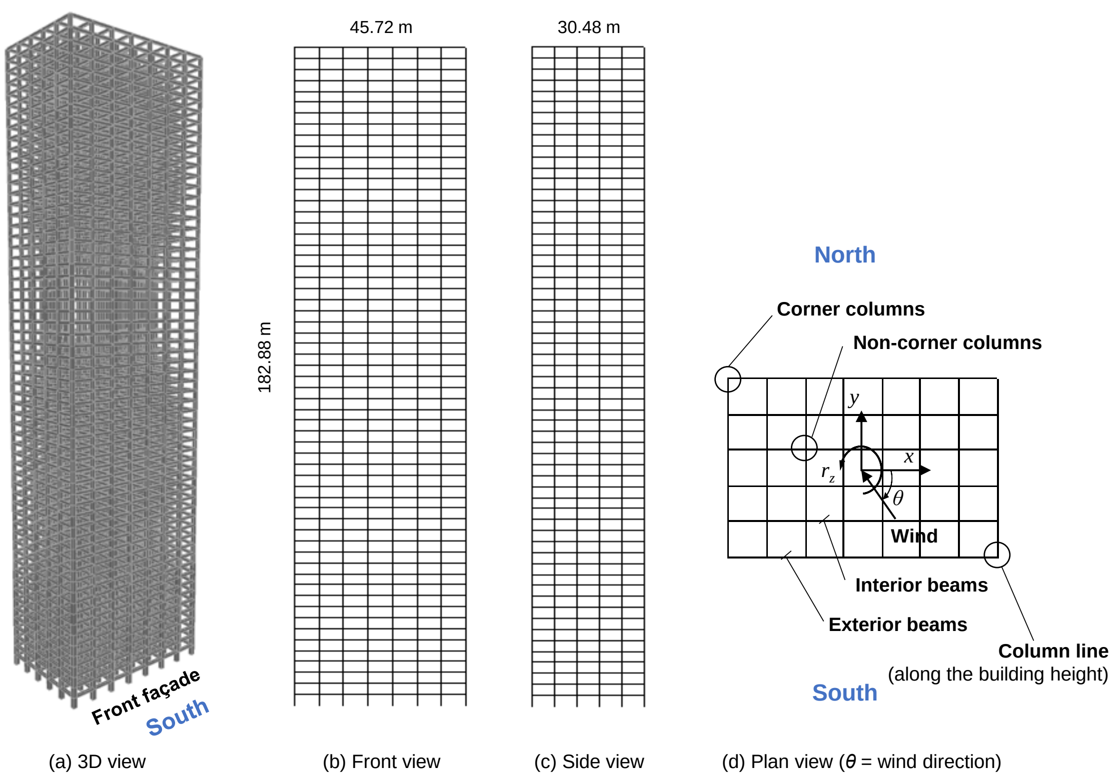


Figure 39. 60-story RC building model

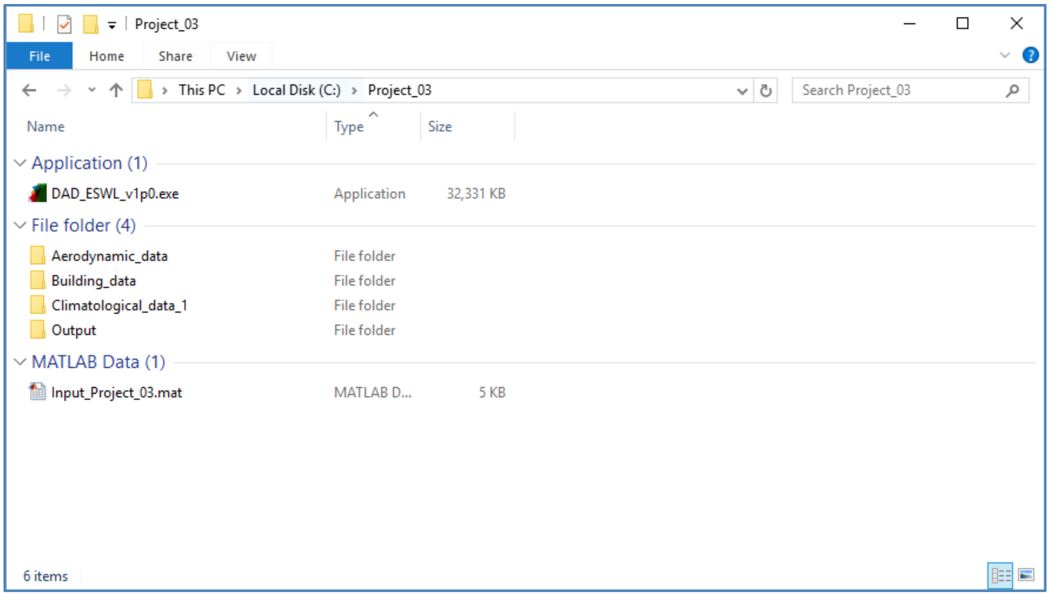


Figure 40. Directory structure for example project 3

Note that the '*Input_Project_03.mat*' file is not the mandatory file for running the software. However, this file is provided for the convenience of the users. It contains all the input values and file path values needed for the example project 3. The users can use this file through the 'Open inputs' button in the software.

5.2 Building's structural data

All the members' cross-sectional dimensions for the preliminary design, D_0, are listed in Table 6. *DAD_ESWL* requires additional sectional properties based on those dimensions, e.g., area, compression strength of concrete, number of rebars, concrete cover depth, nominal areas of rebars, and rebar spacings (see the User's Manual in NIST Technical Note 2000 for details).

After obtaining initial dimensions of the structural members, natural periods of vibration and mode shapes should be calculated by modal analysis using a finite element analysis program. Table 7 lists the natural periods of vibration for the preliminary design D_0. The modal damping ratios were assumed to be 2 % in all six modes considered in this project.

The building's structural data are included in '*Input_RC*' folder. Table 8 lists the structural data required to analyze this example project, and their file name and path.

Table 6. Members' cross-section dimensions (unit = mm)

Name	Story	Section	Longitudinal bar (Longitudinal)	Hoop or stirrup
Corner column	51st ~60th	750 × 750	12 - D29	4 - D13@200
	41st ~50th	750 × 750	12 - D29	4 - D13@200
	31st ~40th	800 × 800	16 - D32	4 - D13@200
	21st ~30th	850 × 850	20 - D32	4 - D16@200
	11th ~20th	900 × 900	20+12 - D43	4 - D16@200
	1st ~10th	1100 × 1100	24+16 - D43	4 - D16@200
Non-corner column	51st ~60th	750 × 750	12 - D25	4 - D13@200
	41st ~50th	750 × 750	12 - D25	4 - D13@200
	31st ~40th	800 × 800	12 - D25	4 - D16@200
	21st ~30th	850 × 850	16 - D29	4 - D16@200
	11th ~20th	900 × 900	20+12 - D43	4 - D16@200
	1st ~10th	1100 × 1100	20+16 - D43	4 - D16@200
Exterior beam	51st ~60th	400 × 700	4 - D32 / 2 - D32	2 - D13@150
	41st ~50th	400 × 700	4+4 - D32 / 3 - D32	2 - D16@150
	31st ~40th	450 × 750	4+4 - D36 / 4 - D32	4 - D16@150
	21st ~30th	500 × 750	5+5 - D36 / 4 - D36	4 - D16@150
	11th ~20th	550 × 750	5+5 - D43 / 4 - D36	4 - D16@150
	1st ~10th	550 × 800	5+5 - D43 / 4 - D36	4 - D16@150
Interior beam	51st ~60th	400 × 700	4 - D29 / 2 - D29	2 - D13@150
	41st ~50th	400 × 700	4+4 - D32 / 2 - D32	2 - D13@150
	31st ~40th	450 × 750	4+4 - D36 / 3 - D32	4 - D13@150
	21st ~30th	500 × 750	5+5 - D36 / 4 - D36	4 - D13@150
	11th ~20th	550 × 750	5+5 - D36 / 4 - D36	4 - D13@150
	1st ~10th	550 × 800	5+5 - D36 / 4 - D36	4 - D13@150

Table 7. Natural periods of vibration

Mode	1st	2nd	3rd	4th	5th	6th
Natural periods [s]	6.404	5.999	5.210	2.221	2.179	1.952

Table 8. Building's structural data

Structural data	File name	Path
Members' list	*RC_members_list.mat*	C:\Project_03\Building_data
Members' properties	*RC_member_properties.mat*	
Mass matrix	*RC_mass_asc.mat*	
Influence coefficients	*RC_dif_all.mat*	
Internal forces by dead load	*RC_frames_DeadLoad.mat*	
Internal forces by super-imposed dead load	*RC_frames_SDeadLoad.mat*	
Internal forces by live load	*RC_frames_LiveLoad.mat*	
Mode shapes	*RC_ModeShapes_pd.mat*	

5.3 Aerodynamic pressure data

The example building is assumed to have suburban terrain exposure. Time series of aerodynamic loads on each floor are calculated from the pressure data induced by wind velocities with wind directions in 10° increments (0°, 10°, …, 350°). The pressure coefficients were measured in wind tunnel tests at the Prato (Italy) Inter-University Research Centre on Building Aerodynamics and Wind Engineering (CRIAC IV-DIC) Boundary Layer Wind Tunnel (Venanzi 2005).

The length scale of the aerodynamic model was 1:500. The duration of the records was 30 s with sampling frequency of 250 Hz for a total approximately 7500 samples for each pressure tap. Hourly mean wind speed at top of the building model during the wind tunnel tests was 23.2 m/s. Since a numerical integration needs a certain number of points before it stabilizes, the first 200 points of the time series are not used in the DAD analysis.

The floor wind load data (*Fl_XXX.mat*, where *XXX* varies from '000' to '360' by in increments of 10) for this example project are included in '*Aerodynamic_data*' folder.

5.4 Climatological wind speed data

This project requires large non-hurricane climatological databases for estimation of wind effects with long MRIs. The non-hurricane (i.e., in this project, synoptic winds) database generated in this project consists of synthetic directional wind speeds in 18 directions for 117600 events. Details on the generation of synthetic wind speed data are provided in Yeo (2014). Terrain exposures at weather station where the hurricane winds were measured and at the location of the building are open (category 'C') and suburban (category 'B'), respectively. The orientation angle of the example building is 270° clockwise from the north, that is, the front façade of the building faces north.

Peak responses are obtained for the DCIs corresponding to a 1700-year MRI. Peak inter-story drifts and accelerations of the building will be obtained from the peak response surfaces for MRI = 20 years and MRI = 10 years, respectively.

The non-hurricane wind speed dataset (*TS_Kansas(182).mat* file) is included in '*Climatological_data_1*' directory.

5.5 Step-by-step tutorial for DAD_ESWL

This section provides step-by-step tutorial for the use of *DAD_ESWL* software to analyze the example building subjected to wind. The tutorial follows the seven tasks (steps) of the DAD procedure shown in Fig. 1.

Step 1. Begin a new model with preliminary design D_0

Select the structural system and determine its preliminary member sizes by using a simplified model of the wind loading (e.g., a static wind loading based on standard provisions). The structural design so achieved is denoted by D_0.

Select the structural system

a. Run **DAD_ESWL_v1p0.exe**, select the **Reinforced Concrete Structure,** and click the **Start** button.

Note. Please wait until the initial page is open. It might take several minutes.

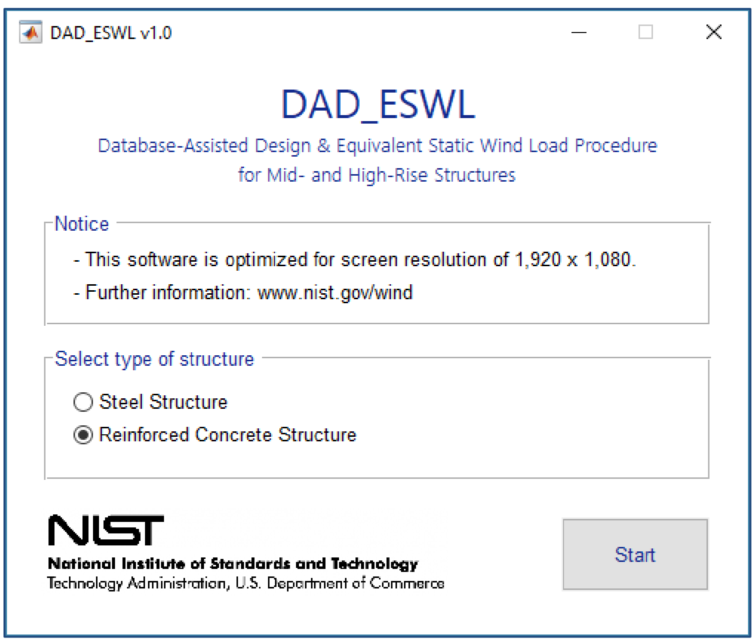


Figure 41. Structural type selection panel

The software will then display the main GUI of the **Bldg. modeling** input panel.

Building information and Analysis type panels:

a. Set the **No. of stories** to **60**.

b. Set the **Building height [m]** to **182.88**.

c. Set the **Building width [m]** to **45.72**.

d. Set the **Building depth [m]** to **30.48**.

e. Set the **Orientation angle [deg.]** to **270**.

f. Click the **Browse** button for **Heights of floors** section. Then select *RC_height_floors.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

g. Click the **Browse** button for **List of all members** section. Then select *RC_members_list.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

h. Click the **Browse** button for **Details of all members** section. Then select *RC_member_properties.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

i. Go to the **Analysis type** section on the right side. Select the **Second-order elastic (P-Delta)** toggle.

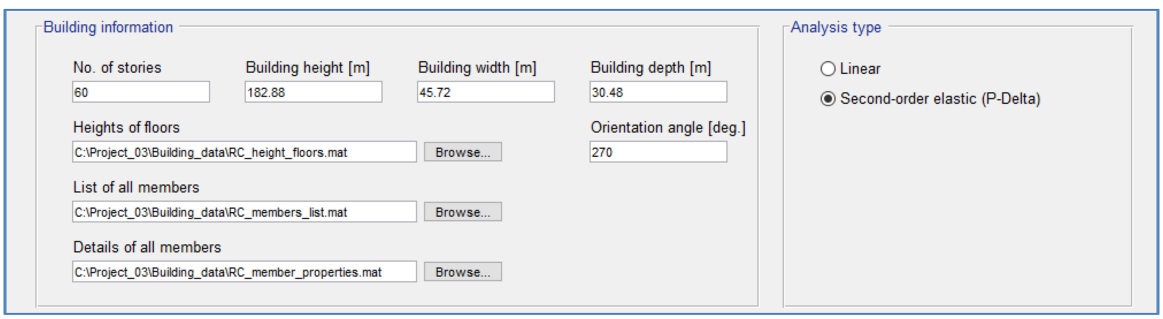


Figure 42. Building information panel

Step 2. Determine the building's structural properties

For the design D_0: determine the building's structural properties, including the modal shapes, natural frequencies of vibration, and damping ratios, as well as the requisite influence coefficients; and develop a lumped-mass model of the structure. *P-Δ* an *P-δ* effects can be accounted for by using, for example, the effective stiffness matrix (Park and Yeo 2018).

Structural properties panel:

a. Set the **No. of modes** to **6**.

b. Set the **Modal damping ratio [%]** to **2 2 2 2 2 2** (Type **2** six times, successive values should be separated by an empty space).

c. Click the **Browse** button for **Mass matrix** section. Then select *RC_mass_asc.mat* file from *Input_RC* folder in the default directory (C:\ Project_03).

d. Select the **Input analysis results from arbitrary FE software**. If you selected the **Second-order elastic (P-Delta)** option, the **Use OpenSees for calculation** section will not be activated.

e. Click the **Browse** button for **Influence coefficients** section. Then select *RC_dif_all.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

f. Click the **Browse** button for **Internal forces due to dead load** section. Then select *RC_frames_DeadLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

g. Click the **Browse** button for **Internal forces due to super-imposed dead load** section. Then select *RC_frames_SDeadLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

h. Click the **Browse** button for **Internal forces due to live load** section. Then select *RC_frames_LiveLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

i. Click the **Browse** button for **Mode shapes** section. Then select *RC_ModeShapes_pd.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

j. Set the **Modal periods [s]** to **6.404 5.999 5.210 2.221 2.179 1.952** (each value should be separated by an empty space).

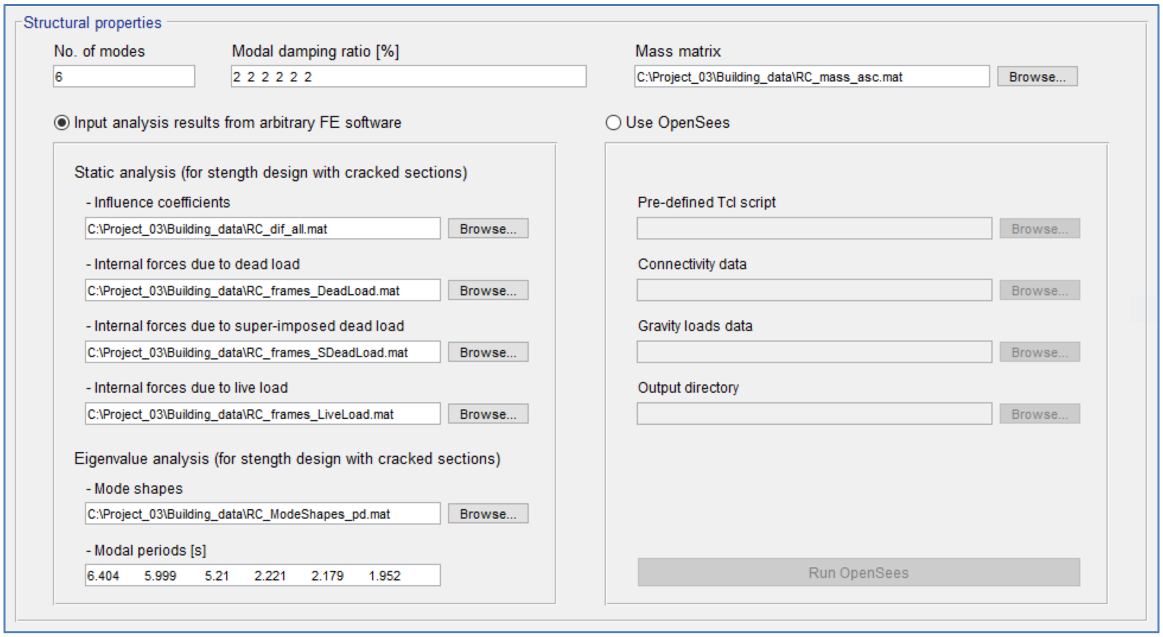


Figure 43. Structural properties panel

k. Move on to the **Wind loads** panel by clicking the **Wind loads** button below.

Step 3. Determine aerodynamic wind loads

From the time histories of simultaneously measured pressure coefficients, determine the time histories of the randomly varying aerodynamic loads induced at all floor levels by mean wind speeds from, depending upon location, 20 m/s to 80 m/s in increments of 10 m/s, say, with directions from $0° \leq \theta_w < 360°$ typically in increments of 10°, say. In this tutorial, we used the wind tunnel data developed at the CRIACIV-DIC Boundary Layer Wind Tunnel (Venanzi 2005).

Wind tunnel test / CWE data panel:

a. Set the **Model length scale [Prototype/Model]** to **500**.

b. Set the **Reference wind speed at rooftop elevation of the building model [m/s]** to **23.2**.

c. Set the **Wind directions [deg.]** to **0:10:360**.

d. Set the **Sampling rate [Hz]** to **250**.

e. Set the **No. of sampling points [points]** to **7504**.

f. Set the **Discarded initial portion of response time series [points]** to **200**.

Move onto the **Floor wind loads at model scale [N and N.m]** section.

g. Select the **Open the floor wind loads**.

h. Click the **Browse** button, and then select *Fl_000.mat* file from *Aerodynamic_data* folder in the default directory (C:\ Project_03). In this folder, the floor wind load data files, *Fl_XXX.mat* where *XXX* varies from ‘000’ to ‘360’ by in increments of 10, must be included.

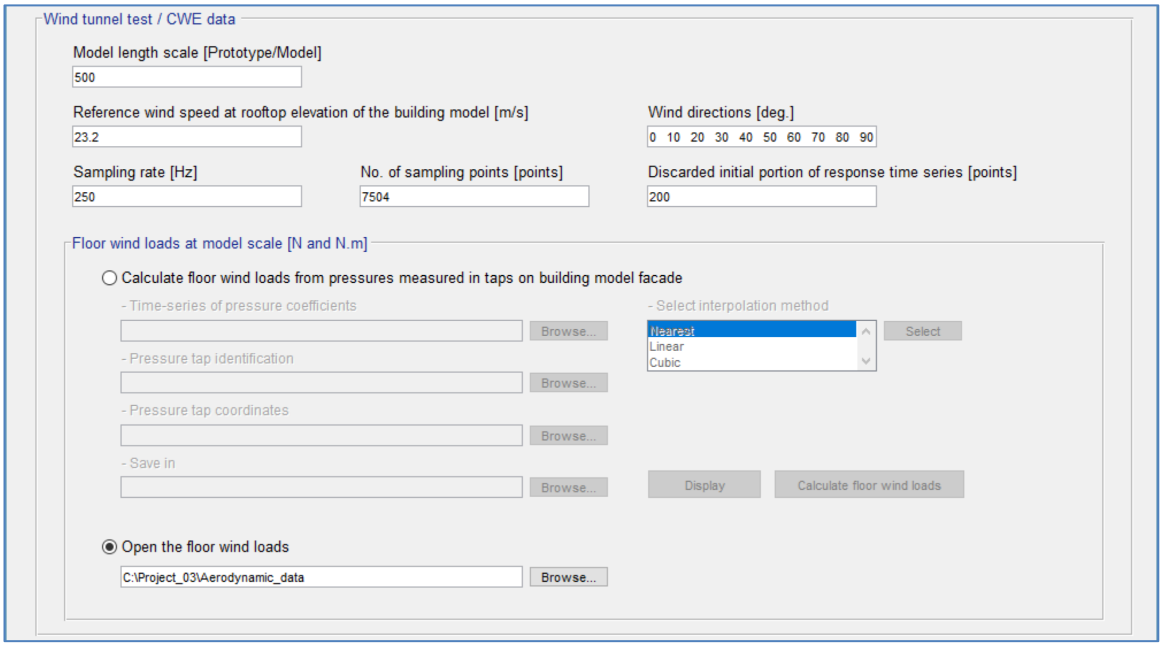


Figure 44. Wind tunnel test / CWE data panel

Wind speed range panel:

a. Set the **Wind speeds for response surfaces [m/s]** to **20:10:80**.

Lower limit requirement panel:

a. Select the **ASCE 7-based overturning moments [N.m]** toggle. Click the **Browse** button and then select *moment_ovtn_ASCE.mat* file from *Building_data* folder in the default directory (C:\Project_03).

b. Click the **80 %** check box on the **Limiting value** section.

Figure 45. Wind speed range and lower limit requirement panel

c. Move on to the **Resp. surface** panel by clicking the **Resp. surface** button below.

Step 4-6. Perform dynamic analysis and construct response surfaces for peak wind effects

Perform the dynamic analysis based on the lumped-mass model of the structure to obtain the time histories of the inertial forces induced by the respective aerodynamic loads, and the effective wind-induced loads consisting of the sums of the aerodynamic and inertial force time histories. The lateral loads are determined at all floor levels of the building. Construct the response surfaces of the peak combined effects (e.g., DCIs, inter-story drift ratio, accelerations) as functions of wind speed and direction.

Load combination cases panel:

a. Set the **Dead load (D)** to **1.2**.

b. Set the **Super-imposed dead load (Ds)** to **1.2**.

c. Set the **Live load (L)** to **1**.

d. Click the **Add** button. The list box above the button will display the load combination case LC1 based on the load factors you set. If your inputs are wrong, click the **Reset** button, then the list box will be empty. Re-input the load factors from the step ‘a’.

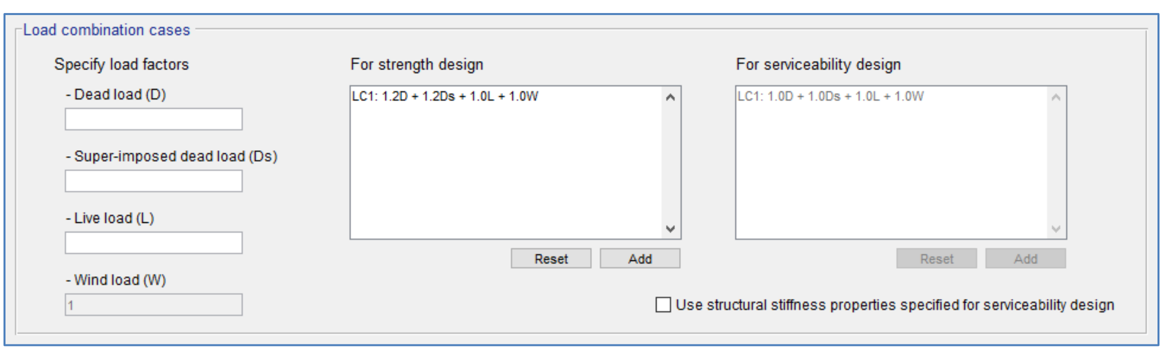


Figure 46. Load combination cases panel

Calculation options panel:

a. Select the **DAD** toggle.

b. Click the **Multiple Points-In-Time approach** check box. Set the points to **30**.

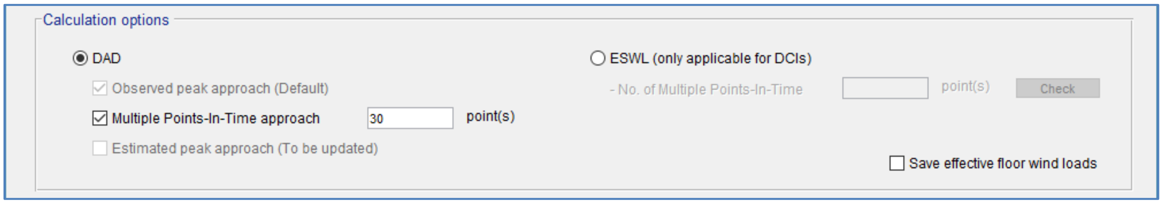


Figure 47. Calculation options panel

Response surface panel:

For the **Demand-to-Capacity Index (DCI)** section,

a. Click the **Browse** button for **Specify members of interest** section. Then select *RC_member_selected_simple.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

Note) The selected members of interest in this example are three columns, member ID = 1, 10, and 20, out of 7800 members.

b. Click the **Browse** button for **Save as** section. Then type **'DCI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_03).

For the **Inter-story drift ratio** section,

c. Click the **Browse** button for **Specify column lines of interest** section. Then select *RC_Interstory_Drift_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

d. Click the **Browse** button for **Save as** section. Then type **'InDr'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_03).

For the **Accelerations** section,

e. Click the **Browse** button for **Specify column lines of interest** section. Then select *RC_Acceleration_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_03).

f. Click the **Browse** button for **Save as** section. Then type **'Acc'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_03).

g. Click the **Compute response surface** button. The pop-up window will then appear to show the progress of the calculation (Fig. 49).

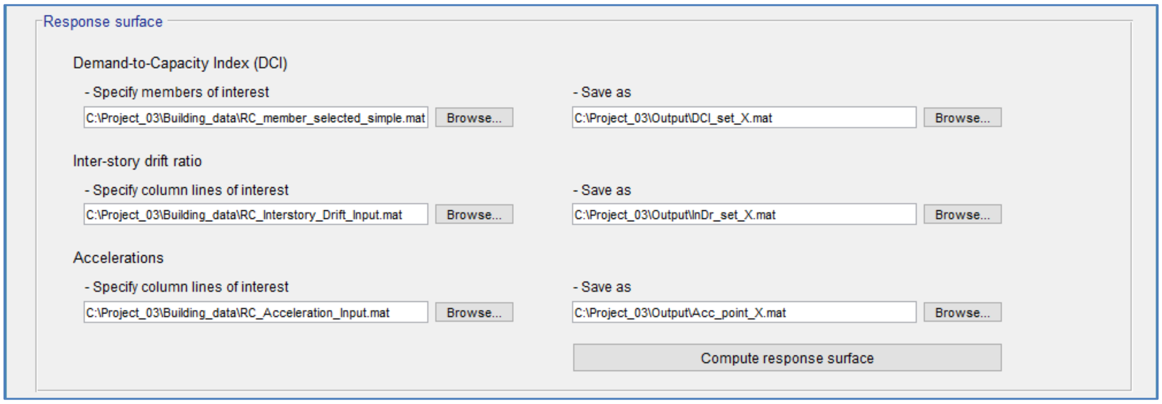


Figure 48. Response surface panel

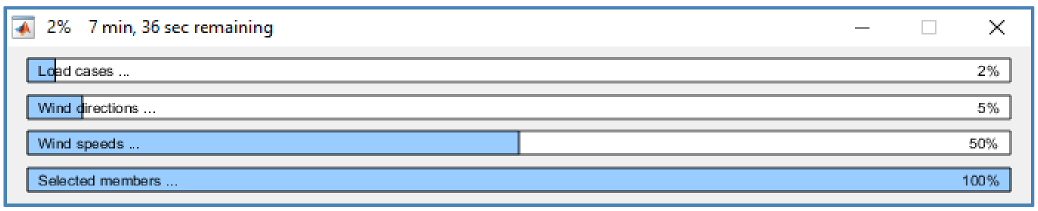


Figure 49. Progress bar

i. Please wait until the calculation is done. This might take several minutes.

j. Once the calculation is done, the progress bar will be automatically disappeared. Then move onto the **Wind effects** panel by clicking the **Wind effects** button below.

Step 7. Determine design wind effects with specified MRIs

Use the information contained in the response surfaces and in the matrices of directional wind speeds at the site to determine, by accounting for wind directionality, the design DCIs with the specified design MRI for the cross sections of interest.

Wind climatological data panel:

a. Select the **Wind climatological data 1** toggle.

b. Click the **Browse** button for **Specify the data file** section. Then select *TS_Kansas(182).mat* file from *Climatological_data_1* directory in the default directory (C:\ Project_03).

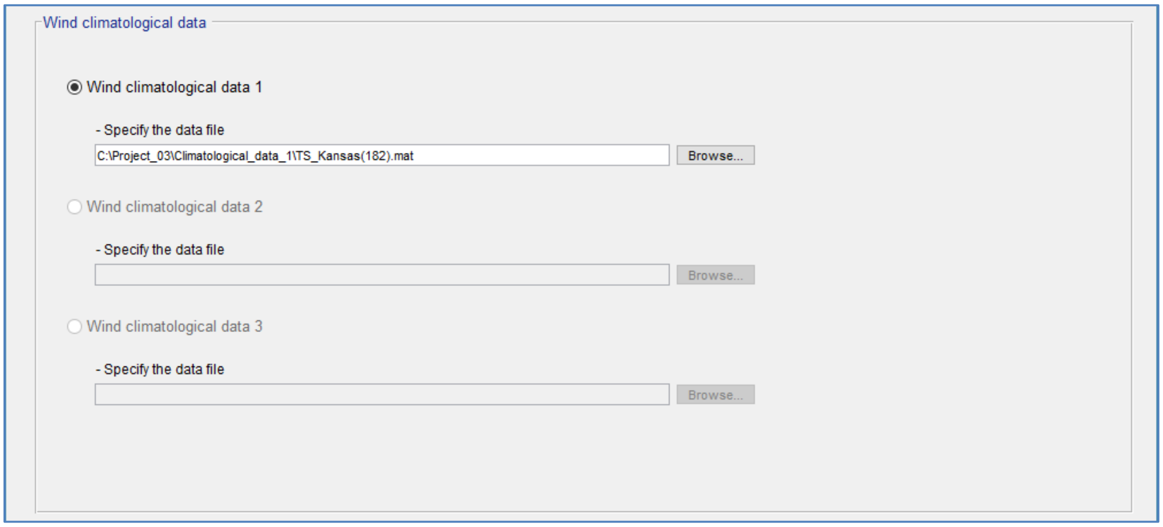


Figure 50. Wind climatological data panel

Design responses for specified MRIs panel:

a. Set the **MRIs for demand-to-capacity index [years]** to **1700**.

b. Click the **Browse** button for **Save as** section. Then type **'DCI_MRI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_03).

c. Set the **MRIs for inter-story drift ratio [years]** to **20**.

d. Click the **Browse** button for **Save as** section. Then type **'InDr_MRI'** as a new filename for inter-story drift results in *Output* folder in the default directory (C:\ Project_03).

e. Set the **MRIs for acceleration [years]** to **10**.

f. Click the **Browse** button for **Save as** section. Then type **'Acc_MRI'** as a new filename for acceleration results in *Output* folder in the default directory (C:\ Project_03).

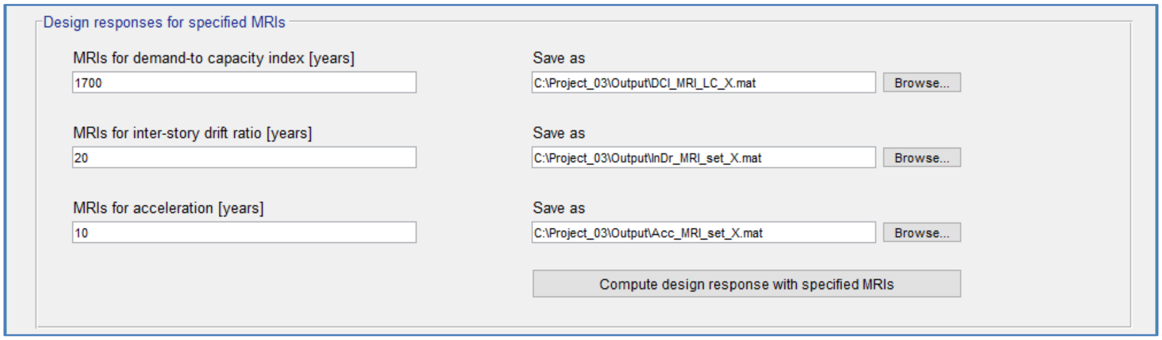


Figure 51. Design responses for specified MRIs panel

g. Click the **Compute design response with specified MRIs** button. The pop-up window will appear to set the number of workers for parallel computing (Fig. 52).

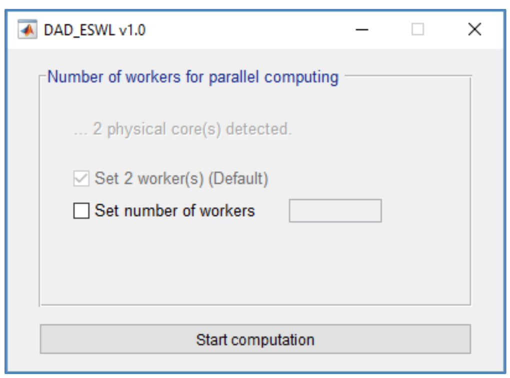


Figure 52. Parallel computing setting dialog

h. After setting the number of workers, click the **Start computation** button. The progress bar will then appear. Please wait until the calculation is done. This might take several minutes.

i. Once the calculation is done, the progress bar will be automatically disappeared. Move onto the **Results & Plots** panel by clicking the **Results & Plot** button below.

5.6 Displaying analysis results for DAD_ESWL

This section provides a tutorial for displaying the analysis results in the software.

Results & Plots panel:

a. Select the **Demand-to-Capacity Index (DCI)** toggle.

b. Select **LC1** from the list box on the **Load case** section. Click the **Check** button.

c. Select **1** from the list box on the **Member** section. Click the **Check** button.

d. Select **1700** from the list box on the **For MRI** section. Click the **Calc** button.

e. Check the values displayed on the boxes below. These values are the peak DCIs with 1700 years-MRI.

f. In the **Plot option** section, click the **DCI**$^{\mathbf{PM}}$ toggle to display the response surface for the DCI^{PM} of the selected member.

g. Click the **Plot response surface** button below the figure displaying area. Then check the response surface (Fig. 56).

h. Click the **Plot deign response** button below the figure displaying area. Then check the peak DCIs depending upon the MRIs (Fig. 57).

i. If you want to edit the figure currently displayed, e.g., rotating a viewing-angle of the figure, moving the objects of figures like legend and title, or saving the figure to local hard drive of your computer, click the **Edit figure** button.

Note 1. For the other wind effects, i.e., **Overturning moment**, **Inter-story drift ratio**, and **Acceleration**, do the same step from 'a' to 'i'. To see a detailed function for each selection, please refer to the User's Manual in NIST Technical Note 2000.

Note 2. For details about the output files you saved in the default folder, '*Output*', please refer to the User's Manual in NIST Technical Note 2000.

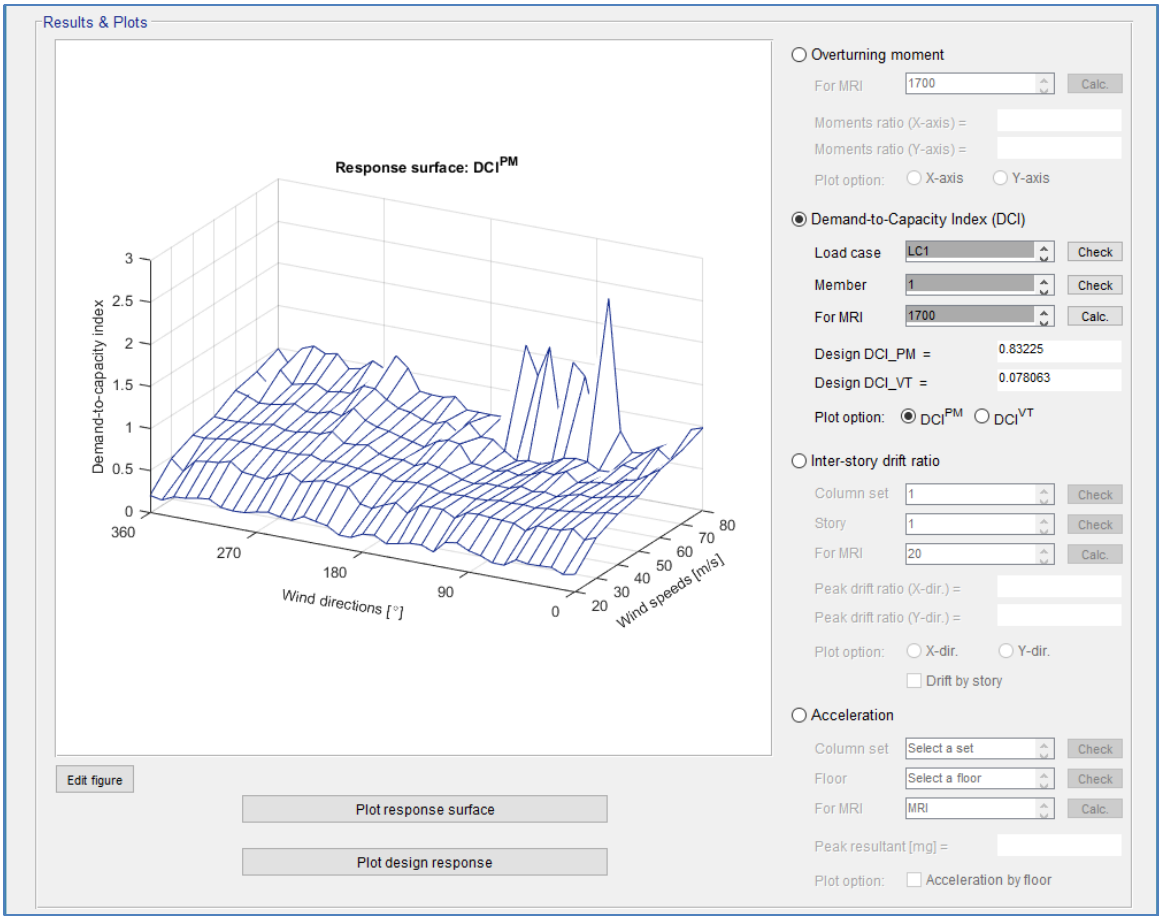


Figure 53. Results & Plots panel: Plot response surface

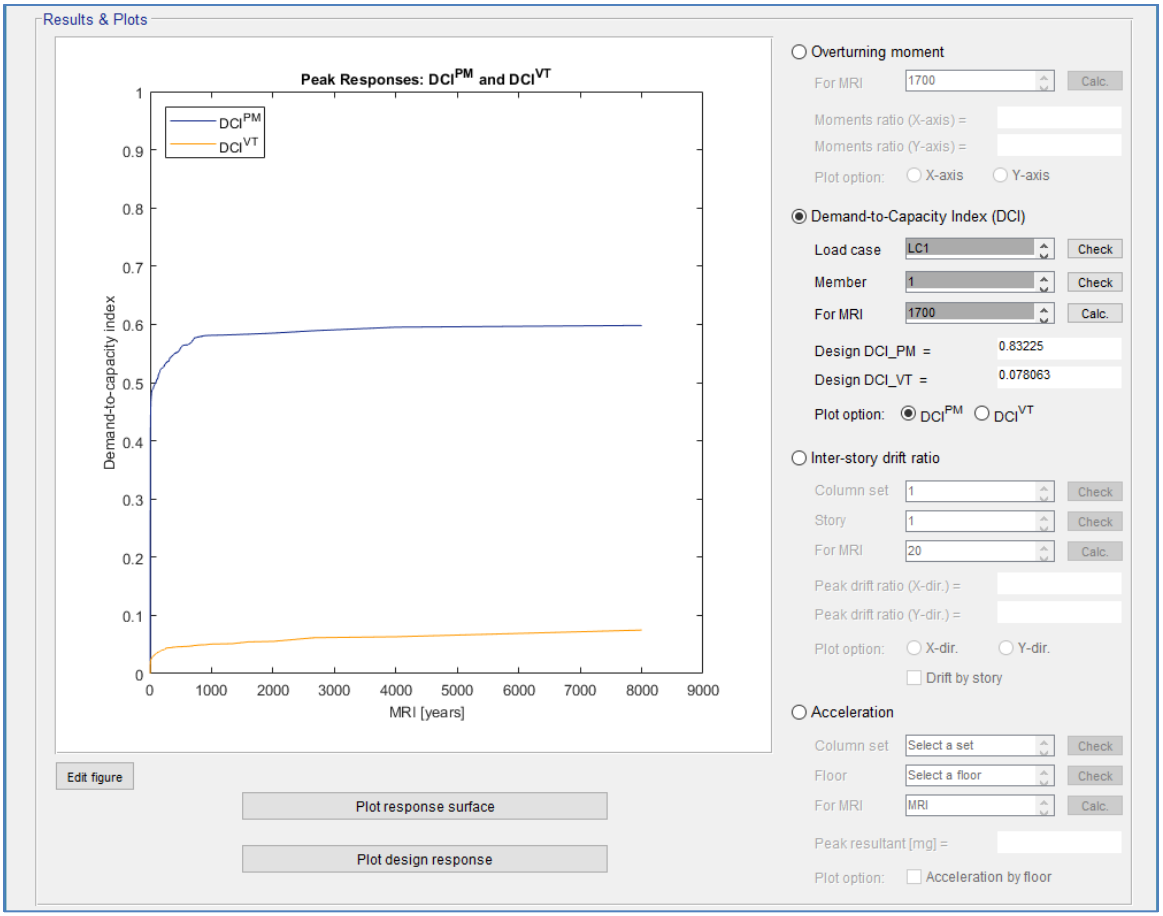


Figure 54. Results & Plots panel: Plot design response

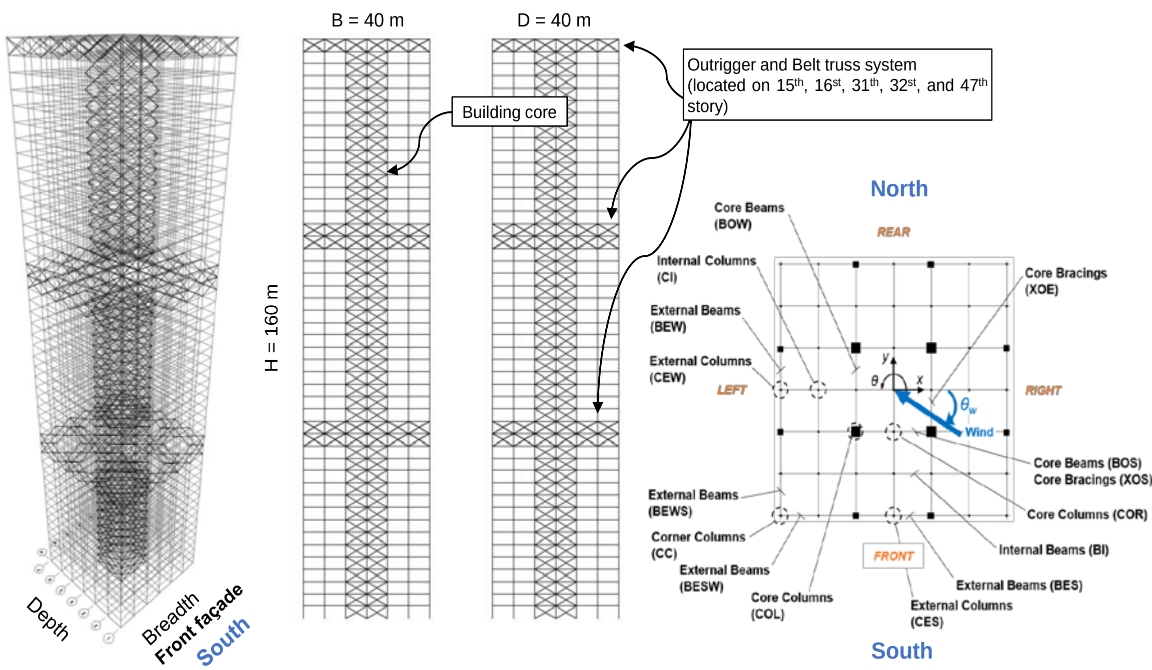
Chapter 6. Example project 4: 47-story steel building I

6.1 Project description

The building being considered in this example is a 47-story steel building with rigid diaphragm floors, outriggers and belt truss system, with a square shape in plan and 40 m × 40 m × 160 m in depth, width and height, respectively (Fig. 55). The structure consists of 2303 columns, 3948 beams, and 2304 diagonal bracings. Columns are divided into three types: core, external core, and interior columns. Beams are divided into three types: exterior, internal, and core beams. Diagonal bracings are divided into two types: core and outrigger bracings. The columns and bracings consist of built-up hollow structural sections (HSS), and the beams consist of rolled W-sections. The building is assumed to be located on the open terrain near South Carolina. The orientation angle of the building is 270° clockwise from the north, that is, the front façade of the building faces north.

This example project will be analyzed by implementing the ESWL procedure with the use of equivalent static wind loads, and they will be converted internally in the software (for details see NIST Tech Note 2000) from the pressure coefficient data from the wind tunnel testing carried out by Tokyo Polytechnic University (TPU). The multiple points-in-time approach with 50 points will be applied for calculation of the ESWL. The second-order effects, i.e., *P-Δ* and *P-δ* effects, will be accounted for. The building is analyzed for gravity and aerodynamic loads with the load combinations 1.2*D* + 1.0*L* + 1.0*W* (denoted by LC1) and 0.9*D* + 1.0*W* (denoted by LC2) where *D* is the total dead load, *L* is the live load, and *W* is the wind load.

To run the project, download a folder named '*Project_04*' from the website http://nist.gov/wind and save it on your local drive C shown in Fig 56.



(a) 3D view (b) Front View (c) Side View (d) Plan view (*θ* = wind direction)

Figure 55. 47-story steel building model

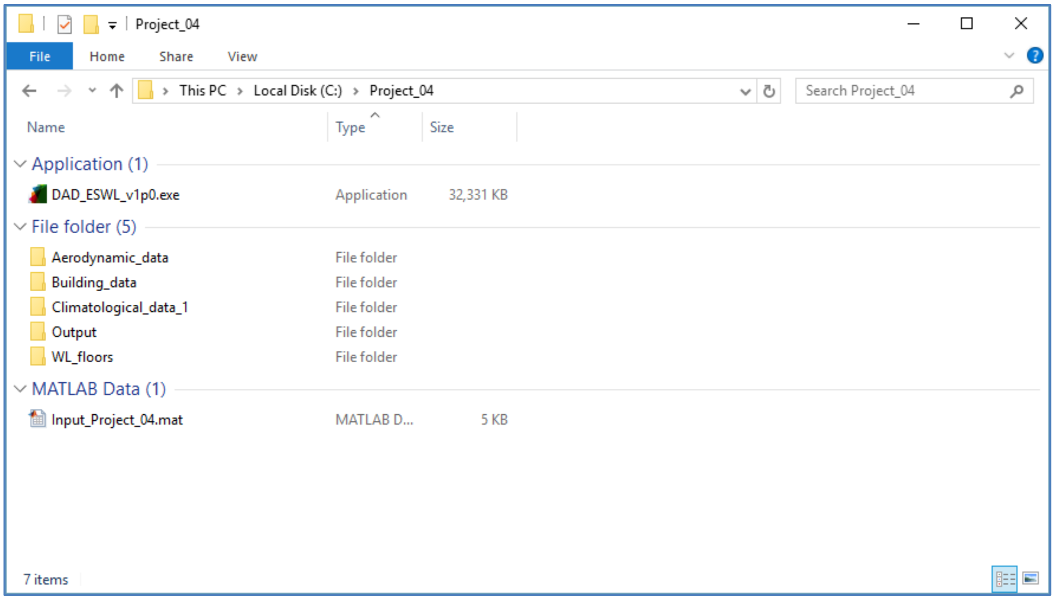


Figure 56. Directory structure for example project 4

It should be noted that the automatically calculated floor wind loading in the *DAD_ESWL* software will be saved in the folder named '*WL_floors*' shown in Fig. 59. This folder will also be automatically generated in the calculation progress of the software. Also, the '*Input_Project_04.mat'* file is not the mandatory file for running the software. However, this file is provided for the convenience of the users. It contains all the input values and file path values needed for the example project 4. The users can use this file through the 'Open inputs' button in the software.

6.2 Building's structural data

All the members' cross-sectional dimensions for the preliminary design, D_0, are listed in Table 9. *DAD_ESWL* requires additional sectional properties based on those dimensions, e.g., area, torsional constant, moment of inertia, shear area, and radius of gyration (see the User's Manual in NIST Technical Note 2000 for details).

After obtaining initial dimensions of the structural members, influence coefficients, internal forces induced by gravity loads of the members, mass matrix, natural periods of vibration, and mode shapes should be calculated by modal analysis using a finite element analysis program. Table 10 lists the natural periods of vibration for the preliminary design D_0. The modal damping ratios are assumed to be 1.5 % in all six modes considered in this project.

The building's structural data are included in '*Input_ST*' folder. Table 11 lists the structural data required to analyze this example project, and their file name and path.

Table 9. Members' cross-section dimensions (unit = mm)

Members' type	Section ID	Sectional type	Depth	Width	Flange thickness	Web thickness
Bracing	1	Box/Tube	350	350	14	14
	2	Box/Tube	300	300	14	14
	3	Box/Tube	200	200	12	12
	4	Box/Tube	145	145	9	9
Column	1	Box/Tube	600	600	35	35
	2	Box/Tube	400	400	15	15
	3	Box/Tube	230	230	10	10
	4	Box/Tube	1800	1800	100	100
	5	Box/Tube	1600	1600	80	80
	6	Box/Tube	1200	1200	50	50
	7	Box/Tube	1300	1300	60	60
	8	Box/Tube	1100	1100	45	45
	9	Box/Tube	1000	1000	40	40
	10	Box/Tube	550	550	24	24
	11	Box/Tube	254	254	13	13
	12	Box/Tube	565	565	25	25
Beam	1	I/Wide Flange	261.62	146.56	11.176	6.604
	2	I/Wide Flange	259.08	102.11	10.033	6.35
	3	I/Wide Flange	251.97	202.95	13.462	8.001

Table 10. Natural periods of vibration

Mode	1st	2nd	3rd	4th	5th	6th
Natural periods [s]	4.593	4.593	4.486	1.762	1.554	1.554

Table 11. Building's structural data

Structural data	File name	Path
Members' list	*ST_members_list.mat*	C:\Project_04\Building_data
Members' properties	*ST_member_properties.mat*	
Mass matrix	*ST_mass_asc.mat*	
Influence coefficients	*ST_dif_all.mat*	
Internal forces by dead load	*ST_frames_DeadLoad.mat*	
Internal forces by super-imposed dead load	*ST_frames_SDeadLoad.mat*	
Internal forces by live load	*ST_frames_LiveLoad.mat*	
Mode shapes	*ST_ModeShapes_pd.mat*	

6.3 Aerodynamic pressure data

The example building is assumed to have open terrain exposure. The aerodynamic pressure time histories were obtained from the Tokyo Polytechnic University (TPU) high-rise building aerodynamic database (http://www.wind.arch.t-kougei.ac.jp/system/eng/contents/code/tpu).

The length scale of the aerodynamic model was 1:400. The duration of the records was 32.8 s with sampling frequency of 1000 Hz for a total 32768 samples for each pressure tap. The mean wind speed at top of the building model during the wind tunnel tests was 11 m/s. Since a numerical integration needs a certain number of points before it stabilizes, the first 500 points of the time series are not used in the analysis.

The aerodynamic pressure coefficient data (*Cp_XXX.mat*, where *XXX* varies from '000' to '360' by in increments of 10) for this example project are included in '*Cp_data*' folder in '*Aerodynamic_data'*.

6.4 Climatological wind speed data

Structural responses to directional wind are obtained by making use of the directional wind speeds of the wind climatological database in conjunction with the response surfaces. The wind climatological database for the calculations presented in this example project is based on a wind speed dataset of 999 simulated hurricanes for 16 directions near South Carolina (Milepost 1950). The minimum hourly wind speed below which the response is no longer of interest is 20 m/s. The orientation angle of the example building is 270° clockwise from the north, that is, the front façade of the building faces north.

Peak responses are obtained for the DCIs corresponding to a 1700-year MRI. Peak inter-story drifts and accelerations of the building will be obtained from the peak response surfaces for MRI = 20 years and MRI = 10 years, respectively.

The wind climatological dataset (*Nhurr_SC(160).mat* file for the milepost 1950) is included in '*Climatological_data_1*' directory, is also available at http://nist.gov/wind.

6.5 Step-by-step tutorial for DAD_ESWL

This section provides step-by-step tutorial for the use of *DAD_ESWL* software to analyze the example building subjected to wind. The tutorial follows the seven tasks (steps) of the DAD procedure shown in Fig. 1.

Step 1. Begin a new model with preliminary design D_0

Select the structural system, and determine its preliminary member sizes by using a simplified model of the wind loading (e.g., a static wind loading based on standard provisions). The structural design so achieved is denoted by D_0.

Select the structural system

a. Run **DAD_ESWL_v1p0.exe**, select the **Steel Structure,** and click the **Start** button.

Note. Please wait until the initial page is open. It might take several minutes.

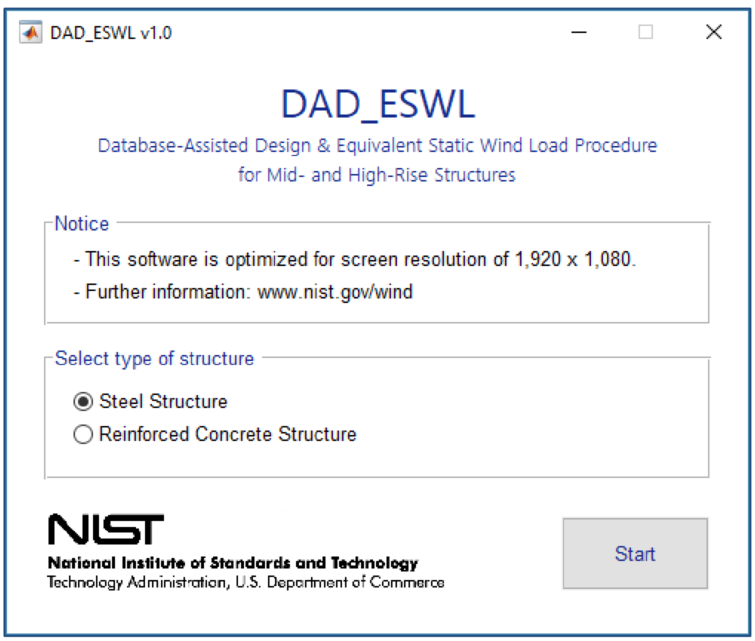


Figure 57. Structural type selection panel

The software will then display the main GUI of the **Bldg. modeling** input panel.

Building information and Analysis type panels:

a. Set the **No. of stories** to **47**.

b. Set the **Building height [m]** to **160**.

c. Set the **Building width [m]** to **40**.

d. Set the **Building depth [m]** to **40**.

e. Set the **Orientation angle [deg.]** to **270**.

f. Click the **Browse** button for **Heights of floors** section. Then select *ST_height_floors.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

g. Click the **Browse** button for **List of all members** section. Then select *ST_members_list.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

h. Click the **Browse** button for **Details of all members** section. Then select *ST_member_properties.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

i. Go to the **Analysis type** section on the right side. Select the **Second-order elastic (P-Delta)** toggle.

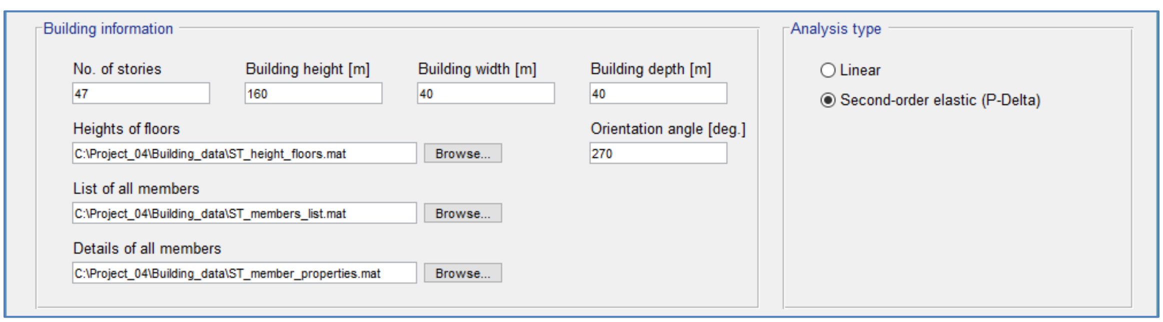


Figure 58. Building information panel

Step 2. Determine the building's structural properties

For the design D_0 (D_2 in this example): determine the building's structural properties, including the modal shapes, natural frequencies of vibration, and damping ratios, as well as the requisite influence coefficients; and develop a lumped-mass model of the structure. P-Δ an P-δ effects can be accounted for by using, for example, the effective stiffness matrix (Park and Yeo 2018).

Structural properties panel:

a. Set the **No. of modes** to **6**.

b. Set the **Modal damping ratio [%]** to **1.5 1.5 1.5 1.5 1.5 1.5** (Type **1.5** six times, successive values should be separated by an empty space).

c. Click the **Browse** button for **Mass matrix** section. Then select *ST_mass_asc.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

d. Select the **Input analysis results from arbitrary FE software**. If you selected the **Second-order elastic (P-Delta)** option, the **Use OpenSees for calculation** section will not be activated.

e. Click the **Browse** button for **Influence coefficients** section. Then select *ST_dif_all.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

f. Click the **Browse** button for **Internal forces due to dead load** section. Then select *ST_frames_DeadLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

g. Click the **Browse** button for **Internal forces due to super-imposed dead load** section. Then select *ST_frames_SDeadLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

h. Click the **Browse** button for **Internal forces due to live load** section. Then select *ST_frames_LiveLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

i. Click the **Browse** button for **Mode shapes** section. Then select *ST_ModeShapes_pd.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

j. Set the **Modal periods [s]** to **4.066 4.066 3.960 1.567 1.412 1.412** (each value should be separated by an empty space).

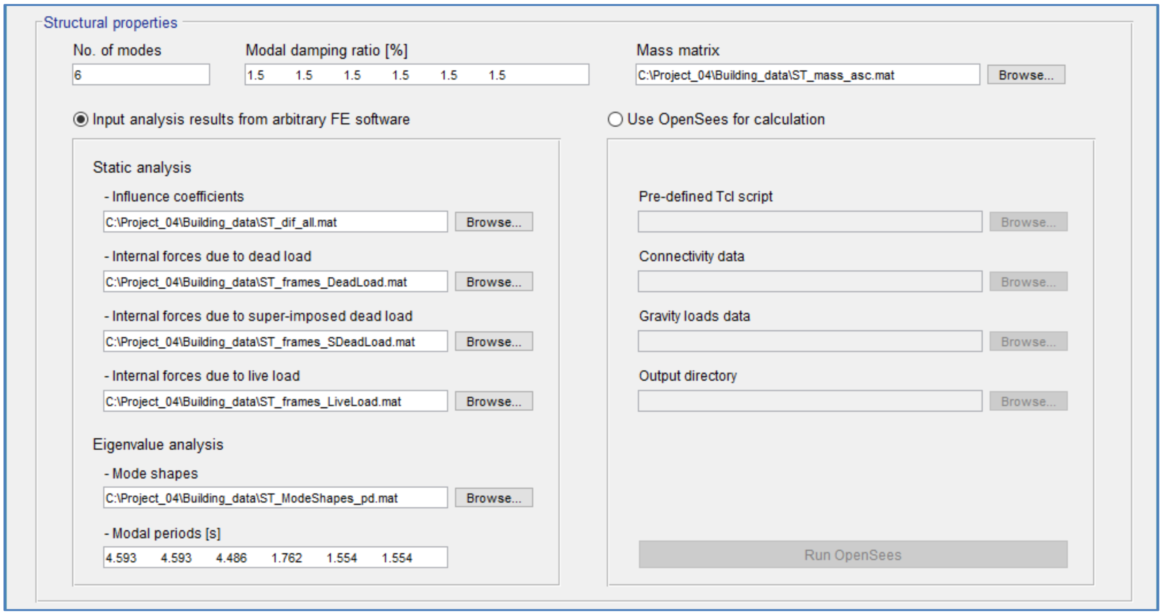


Figure 59. Structural properties panel

k. Move on to the **Wind loads** panel by clicking the **Wind loads** button below.

Step 3. Determine aerodynamic wind loads

From the time histories of simultaneously measured pressure coefficients, determine the time histories of the randomly varying aerodynamic loads induced at all floor levels by mean wind speeds from, depending upon location, 20 m/s to 80 m/s in increments of 10 m/s, say, with directions from $0° \leq \theta < 360°$ typically in increments of 10°, say.

Wind tunnel test / CWE data panel:

a. Set the **Model length scale [Prototype/Model]** to **400**.

b. Set the **Reference wind speed at rooftop elevation of the building model [m/s]** to **11.0005**.

c. Set the **Wind directions [deg.]** to **0:10:360**.

d. Set the **Sampling rate [Hz]** to **1000**.

e. Set the **No. of sampling points [points]** to **32768**.

f. Set the **Discarded initial portion of response time series [points]** to **500**.

Move onto the **Floor wind loads at model scale [N and N.m]** section.

g. Select the **Calculate floor wind loads from pressures measured in taps on building model façade**. The input sections below will then be activated.

h. Click the **Browse** button for **Time-series of pressure coefficients** section. Then select *Cp_data* directory from *Aerodynamic_data* folder in the default directory (C:\Project_04). In the *Cp_data* directory, the pressure coefficient data files, *Cp_XXX.mat* where *XXX* varies from ‘000’ to ‘360’ by in increments of 10, must be included.

i. Click the **Browse** button for **Pressure tap identification** section. Then select *tap_loc.mat* file from *Aerodynamic_data* folder in the default directory (C:\Project_04).

j. Click the **Browse** button for **Pressure tap coordinates** section. Then select *tap_coord.mat* file from *Aerodynamic_data* folder in the default directory (C:\Project_04).

k. Select **Cubic** in the **Select interpolation method** section, then click the **Select** button.

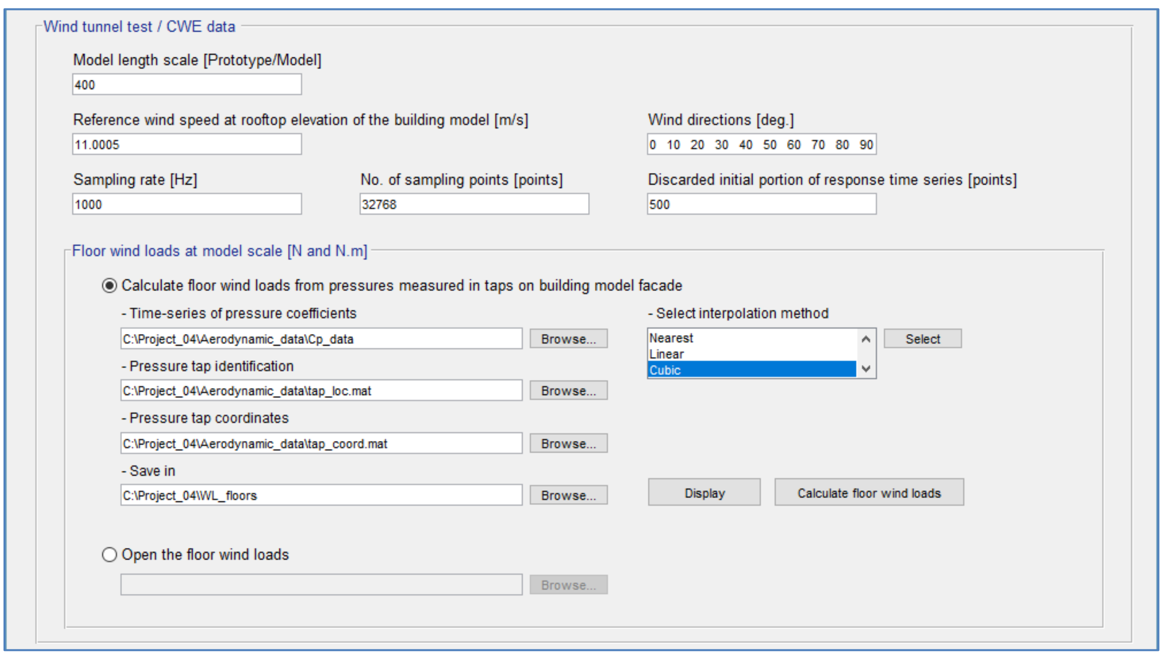


Figure 60. Wind tunnel test / CWE data panel

Note 1. Mandatory input files for the pressure data (*Cp_XXX.mat*), tap location (*tap_loc.mat*), and tap coordinates (*tap_coord.mat*) must be created in advance from wind tunnel test or CFD analysis. The formats and structures required for those input files are described in the User's Manual in NIST Technical Note 2000 (Section 4.2).

Note 2. You can check the wind pressure information (i.e., location of pressure taps, time-series of the pressure coefficients at each tap, pressure contour on each façade of building model) by clicking the **Display** button below. Please refer to the User's Manual in NIST Technical Note 2000 for details.

l. Click the **Browse** button for **Save in** section. Then select *WL_floors* folder from the default directory (C:\Project_04).

m. Click the **Calculate floor wind loads** button. The software will be starting the calculation of the floor wind loads automatically. A pop-up window to show the calculation progress will appear.

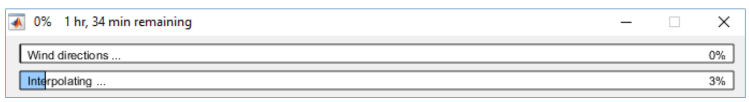


Figure 61. Computation of floor wind loads

m. During the calculation, the **Calculate floor wind loads** button will become inactive, and show a message that **'Calculating wind loads … busy'**. The calculation might take from minutes to hours depending on the size of the pressure time-series, the number of taps, and the interpolating method the users selected. After the calculation, a message **'Done'** will be displayed, and you can proceed to the next stage.

Note. The floor wind load data for each wind direction will be saved in the new folder named *WL_floors* in the default directory (C:\Project_04).

Wind speed range panel:

a. Set the **Wind speeds for response surfaces [m/s]** to **20:10:80**.

Lower limit requirement panel:

a. Select the **ASCE 7-based overturning moments [N.m]** toggle. Click the **Browse** button and then select *moment_ovtn_ASCE.mat* file from *Building_data* folder in the default directory (C:\Project_04).

b. Click the **80 %** check box on the **Limiting value** section.

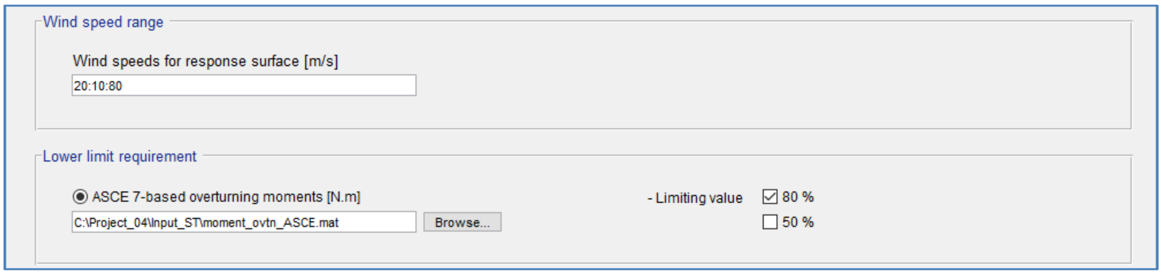


Figure 62. Wind speed range and lower limit requirement panel

b. Move on to the **Resp. surface** panel by clicking the **Resp. surface** button below.

Step 4a-6. Perform dynamic analysis and construct response surfaces for wind effects

Perform the dynamic analysis based on the lumped-mass model of the structure to obtain the time histories of the inertial forces induced by the respective aerodynamic loads, and the effective wind-induced loads consisting of the sums of the aerodynamic and inertial force time histories. The lateral loads are determined at all floor levels of the building. Construct the response surfaces of the peak combined effects (e.g., DCIs, inter-story drift ratio, accelerations) as functions of wind speed and direction.

Load combination cases panel:

a. Set the **Dead load (D)** to **1.2**.

b. Set the **Super-imposed dead load (Ds)** to **1.2**.

c. Set the **Live load (L)** to **1**.

d. Click the **Add** button. The list box above the button will display the load combination case LC1 based on the load factors you set. If your inputs are wrong, click the **Reset** button, then the list box will be empty. Re-input the load factors from the step ‘a’.

e. Create LC2 in the same way. The load factors for **D**, **Ds**, and **L** are **0.9**, **0.9**, and **0**, respectively.

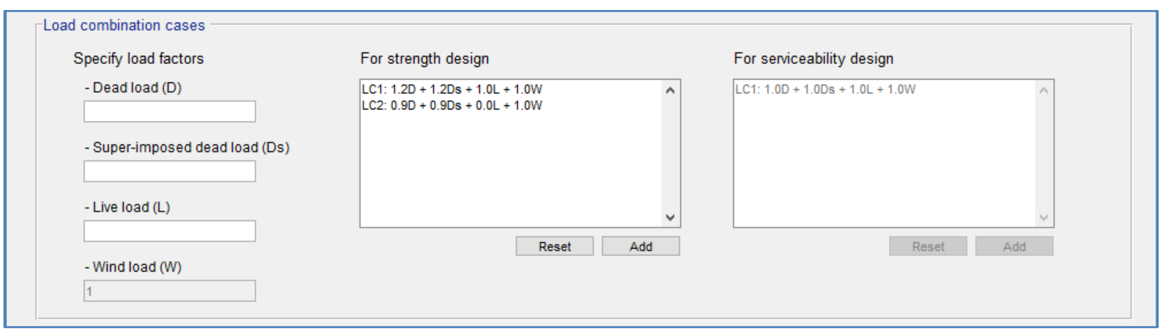


Figure 63. Load combination cases panel

Calculation options panel:

a. Select the **ESWL (only applicable for DCIs)** toggle.

b. Set the points to **50** for **No. of Multiple Points-In-Time** section.

c. Click the **Check** button. A pop-up dialog will appear as shown in Fig. 68. Confirm the number of wind loading cases and click the **OK** button to proceed the next step.

Figure 64. Calculation options panel

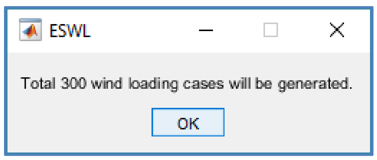


Figure 65. ESWL dialog

Response surface panel:

For the **Demand-to-Capacity Index (DCI)** section,

a. Click the **Browse** button for **Specify members of interest** section. Then select *ST_member_selected_simple.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

Note) The selected members of interest in this example are three columns, member ID = 1, 10, and 20, out of 8555 members.

b. Click the **Browse** button for **Save as** section. Then type **'DCI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_04).

For the **Inter-story drift ratio** section,

c. Click the **Browse** button for **Specify column lines of interest** section. Then select *ST_Interstory_Drift_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

d. Click the **Browse** button for **Save as** section. Then type **‘InDr’** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_04).

For the **Accelerations** section,

e. Click the **Browse** button for **Specify column lines of interest** section. Then select *ST_Acceleration_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_04).

f. Click the **Browse** button for **Save as** section. Then type **‘Acc’** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_04).

g. Click the **Compute response surface** button. The pop-up window will then appear to show the progress of the calculation (Fig. 70).

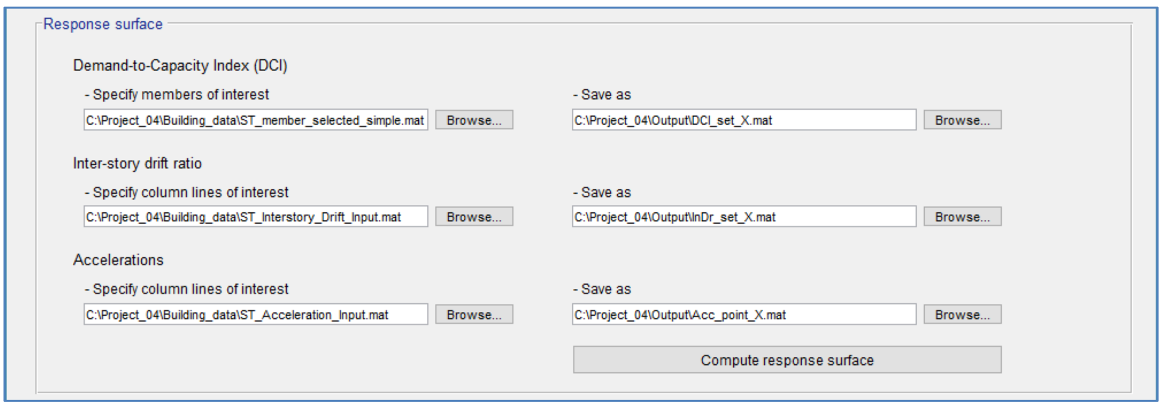


Figure 66. Response surface panel

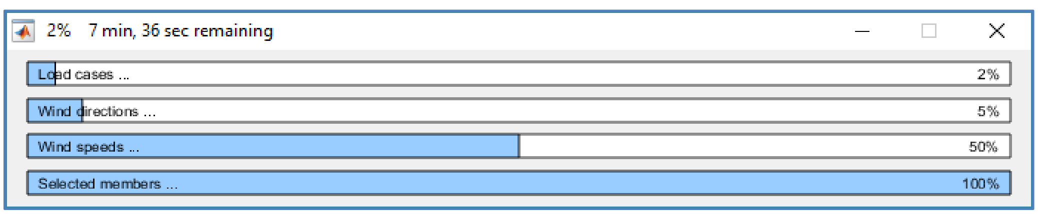


Figure 67. Progress bar

i. Please wait until the calculation is done. This might take several minutes.

j. Once the calculation is done, the progress bar will be automatically disappeared. Then move onto the **Wind effects** panel by clicking the **Wind effects** button below.

Step 7. Determine design wind effects with specified MRIs

Use the information contained in the response surfaces and in the matrices of directional wind speeds at the site to determine, by accounting for wind directionality, the design DCIs with the specified design MRI for the cross sections of interest.

Wind climatological data panel:

a. Select the **NIST Hurricane wind speed data** toggle.

b. Click the **Browse** button for **Specify the data file** section. Then select *Nhurr_SC(160).mat* file from the *Climatological_data_1* directory from the default directory (C:\ Project_04).

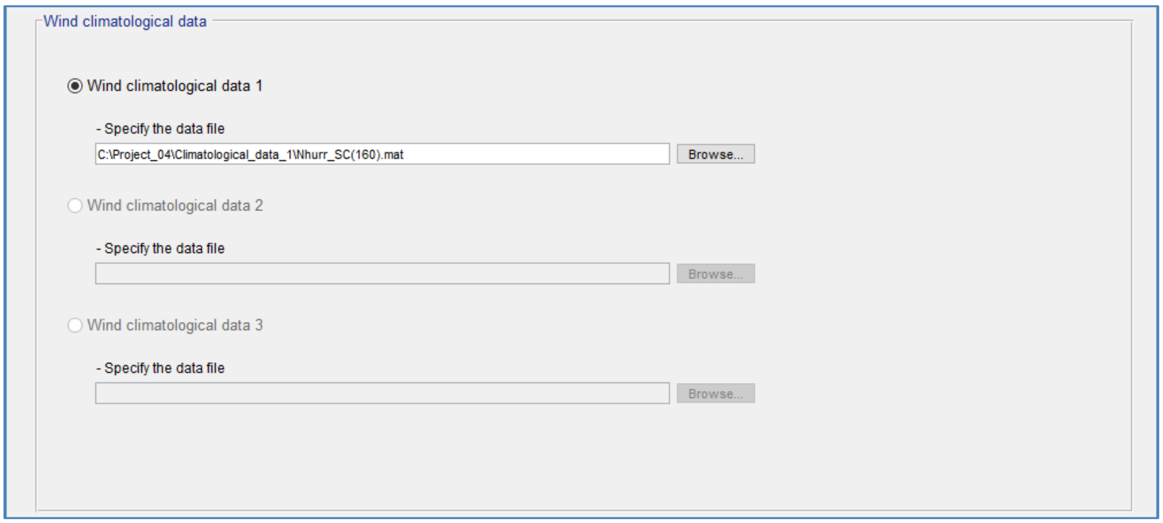


Figure 68. Wind climatological data panel

Design responses for specified MRIs panel:

a. Set the **MRIs for demand-to-capacity index [years]** to **1700**.

b. Click the **Browse** button for **Save as** section. Then type **'DCI_MRI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_04).

c. Set the **MRIs for inter-story drift ratio [years]** to **20**.

d. Click the **Browse** button for **Save as** section. Then type **'InDr_MRI'** as a new filename for inter-story drift results in *Output* folder in the default directory (C:\ Project_04).

e. Set the **MRIs for acceleration [years]** to **10**.

f. Click the **Browse** button for **Save as** section. Then type **'Acc_MRI'** as a new filename for acceleration results in *Output* folder in the default directory (C:\ Project_04).

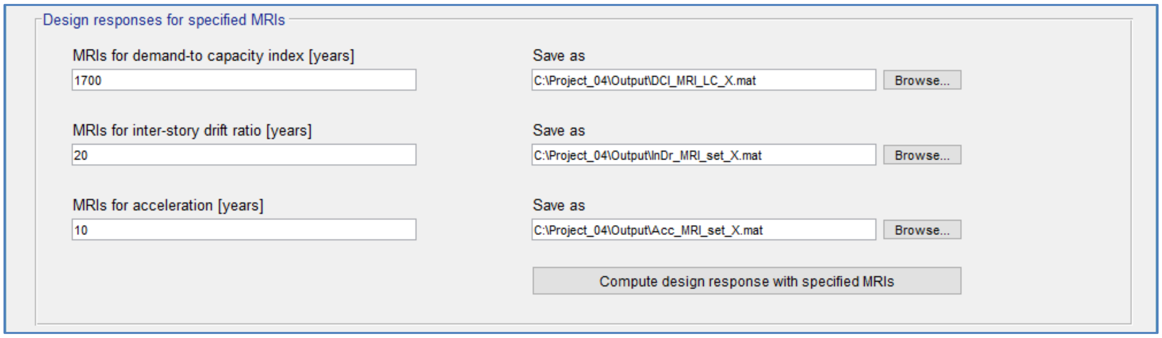


Figure 69. Design responses for specified MRIs panel

g. Click the **Compute peak response with specified MRIs** button. The pop-up window will appear to check whether the response surface was constructed for the entire set of wind directions (Fig. 74).

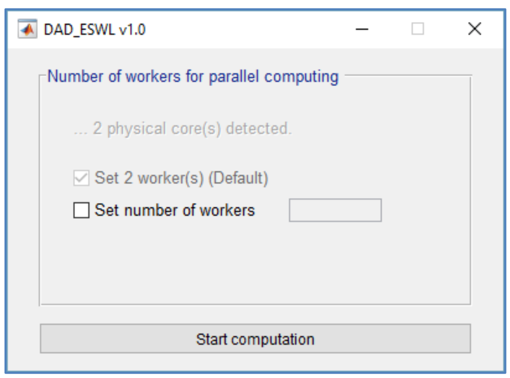


Figure 70. Parallel computing setting dialog

h. After setting the number of workers, click the **Start computation** button. The progress bar will then appear. Please wait until the calculation is done. This might take several minutes.

i. Once the calculation is done, the progress bar will be automatically disappeared. Move onto the **Results & Plots** panel by clicking the **Results & Plot** button below.

6.6 Displaying analysis results for DAD_ESWL

This section provides a tutorial for displaying the analysis results in the software.

Results & Plots panel:

a. Select the **Demand-to-Capacity Index (DCI)** toggle.

b. Select **Combo max. case** from the list box on the **Load case** section. Click the **Check** button.

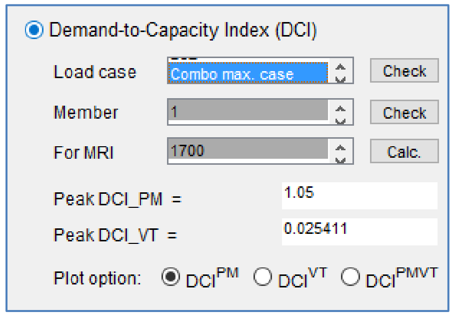


Figure 71. Demand-to-Capacity Index (DCI) section

c. Select **1** from the list box on the **Member** section. Click the **Check** button.

d. Select **1700** from the list box on the **For MRI** section. Click the **Calc** button.

e. Check the values displayed on the boxes below. These values are the peak DCIs with 1700 years-MRI for the envelopment of the peak DCI results from the two load combinations, LC1 and LC2.

f. In the **Plot option** section, click the **DCI^{PM}** toggle to display the response surface for the DCI^{PM} of the selected member.

g. Click the **Plot response surface** button below the figure displaying area. Then check the response surface (Fig. 77).

Note) If you click the **Plot response surface** button with the **Combo max. case** selected in the **Load case** section, an error message will appear as shown in Fig. 76. Plotting the response surface for the combination maximum case is not supported.

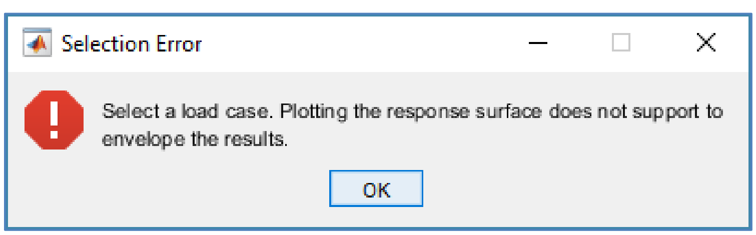


Figure 72. Error message for plot response surface

h. Click the **Plot design response** button below the figure displaying area. Then check the peak DCIs depending upon the MRIs (Fig. 78).

i. If you want to edit the figure currently displayed, e.g., rotating a viewing-angle of the figure, moving the objects of figures like legend and title, or saving the figure to local hard drive of your computer, click the **Edit figure** button.

Note 1. For the other wind effects, i.e., **Overturning moment**, **Inter-story drift ratio**, and **Acceleration**, do the same step from ‘a’ to ‘i’. To see a detailed function for each selection, please refer to the User’s Manual in NIST Technical Note 2000.

Note 2. For details about the output files you saved in the default folder, ‘*Output*’, please refer to the User’s Manual in NIST Technical Note 2000.

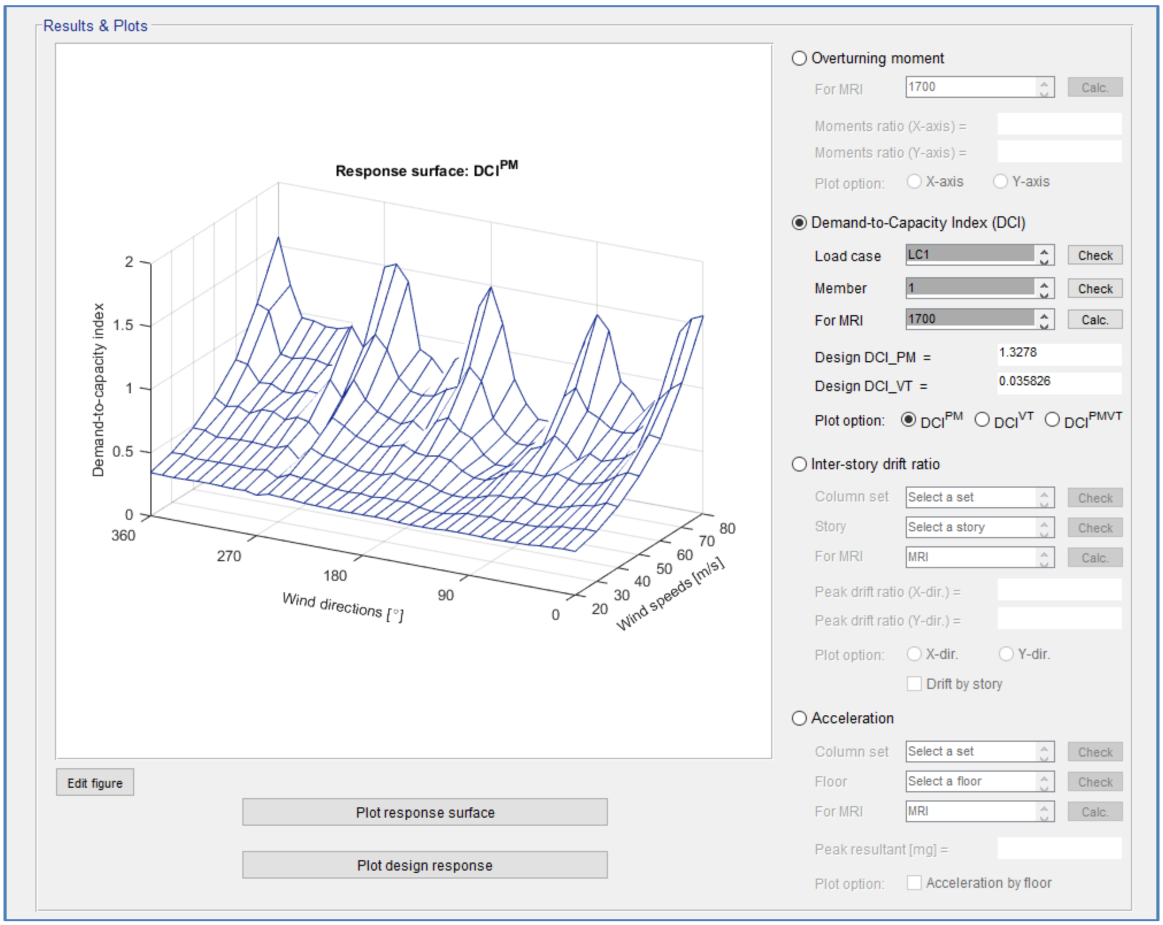


Figure 73. Results & Plots panel: Plot response surface

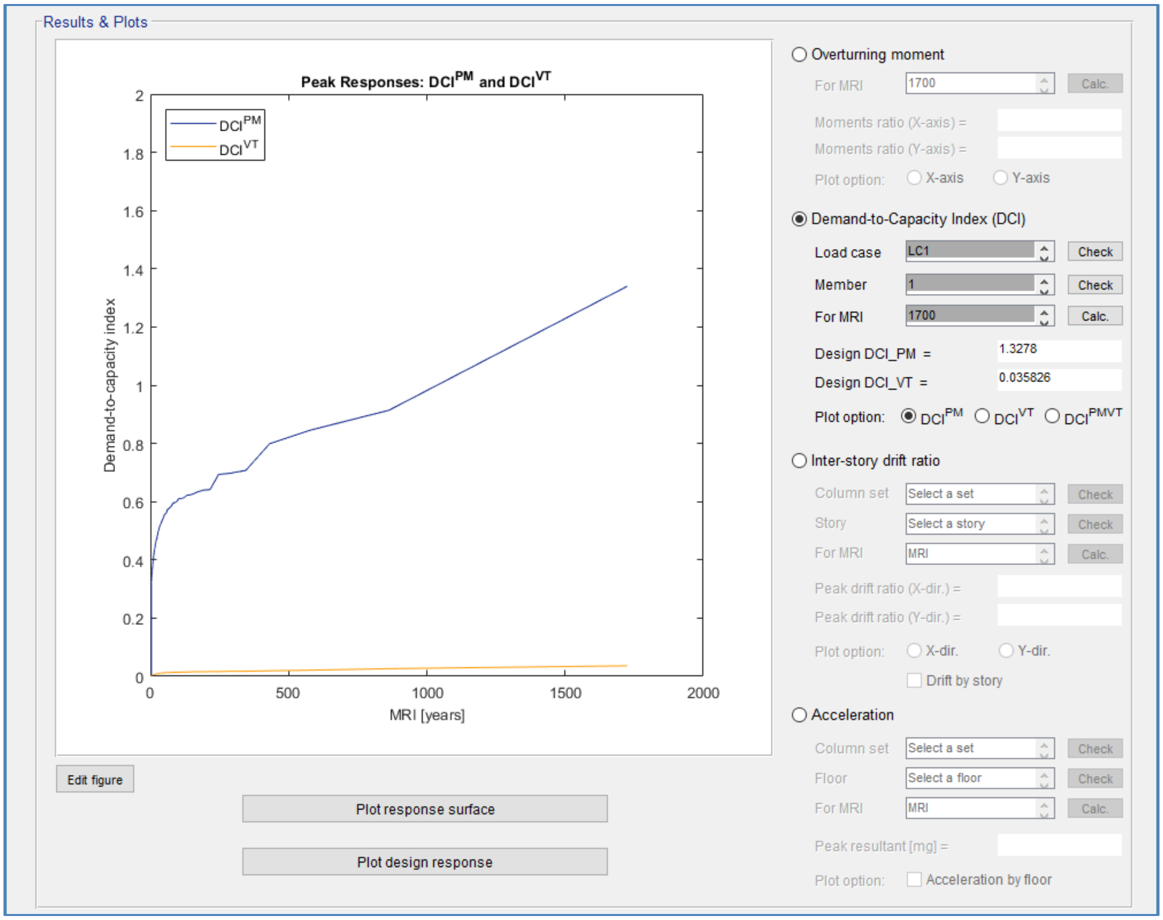


Figure 74. Results & Plots panel: Plot design response

Chapter 7. Example project 5: 47-story steel building II

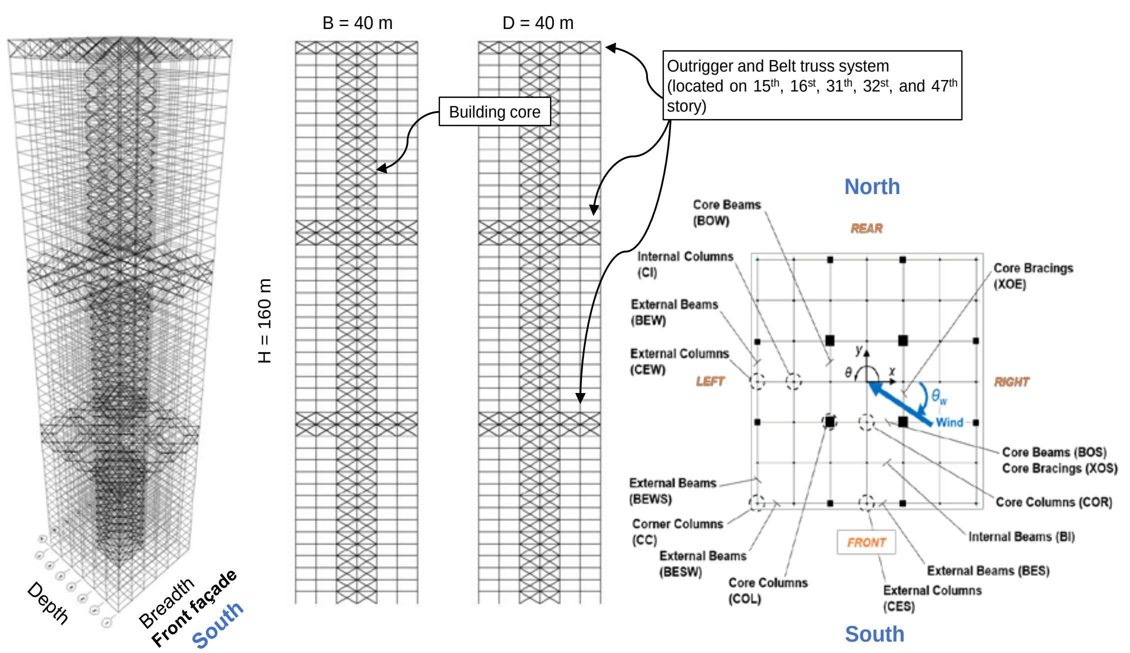
7.1 Project description

The 47-story steel building, which is identical to the example project 4, will be analyzed by implementing the DAD procedure with the use of randomly fluctuating wind loads acting at each floor.

The building being considered in this example is a 47-story steel building with rigid diaphragm floors, outriggers and belt truss system, with a square shape in plan and 40 m × 40 m × 160 m in depth, width and height, respectively (Fig. 75). The structure consists of 2303 columns, 3948 beams, and 2304 diagonal bracings. Columns are divided into three types: core, external core, and interior columns. Beams are divided into three types: exterior, internal, and core beams. Diagonal bracings are divided into two types: core and outrigger bracings. The columns and bracings consist of built-up hollow structural sections (HSS), and the beams consist of rolled W-sections. The building is assumed to be located on the open terrain near South Carolina. The orientation angle of the building is 270° clockwise from the north, that is, the front façade of the building faces north.

The aerodynamic wind loading will be converted internally in the software (for details see NIST Tech Note 2000) from the pressure coefficient data from the wind tunnel testing carried out by Tokyo Polytechnic University (TPU). The multiple points-in-time approach with 30 points will be applied. The second-order effects, i.e., *P-Δ* and *P-δ* effects, will be accounted for. The building is analyzed for gravity and aerodynamic loads with the load combinations 1.2*D* + 1.0*L* + 1.0*W* (denoted by LC1) and 0.9*D* + 1.0*W* (denoted by LC2) where *D* is the total dead load, *L* is the live load, and *W* is the wind load.

To run the project, download a folder named '*Project_05*' from the website http://nist.gov/wind and save it on your local drive C shown in Fig 76.



(a) 3D view (b) Front View (c) Side View (d) Plan view (θ = wind direction)

Figure 75. 47-story steel building model

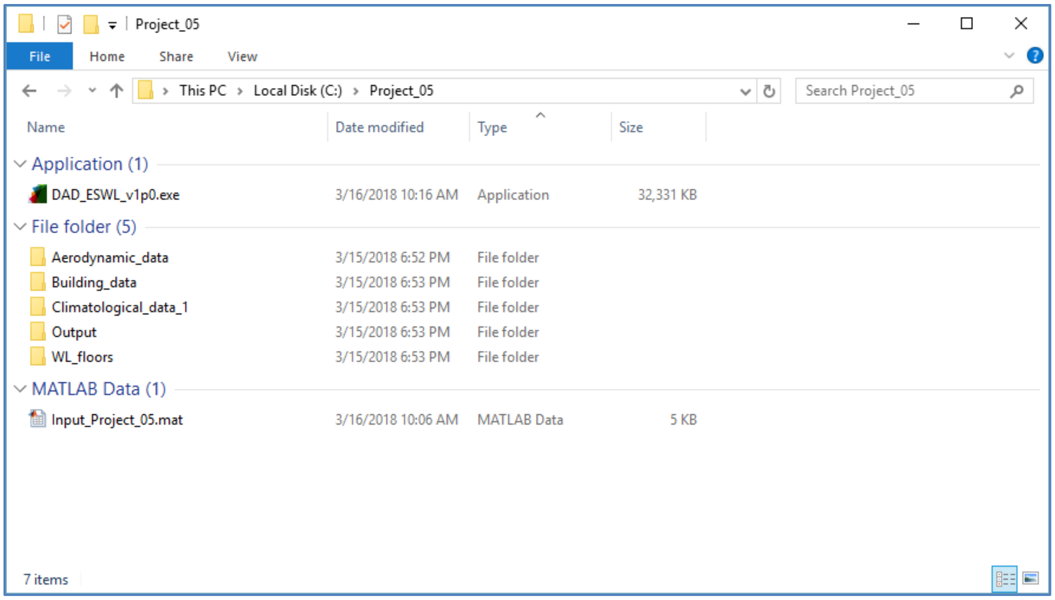


Figure 76. Directory structure for example project 5

It should be noted that the automatically calculated floor wind loading in the *DAD_ESWL* software will be saved in the folder named '*WL_floors*' shown in Fig. 80. This folder will also be automatically generated in the calculation progress of the software. Also, the '*Input_Project_05.mat'* file is not the mandatory file for running the software. However, this file is provided for the convenience of the users. It contains all the input values and file path values needed for the example project 5. The users can use this file through the 'Open inputs' button in the software.

7.2 Building's structural data

All the members' cross-sectional dimensions for the preliminary design, D_0, are listed in Table 12. *DAD_ESWL* requires additional sectional properties based on those dimensions, e.g., area, torsional constant, moment of inertia, shear area, and radius of gyration (see the User's Manual in NIST Technical Note 2000 for details).

After obtaining initial dimensions of the structural members, influence coefficients, internal forces induced by gravity loads of the members, mass matrix, natural periods of vibration, and mode shapes should be calculated by modal analysis using a finite element analysis program. Table 13 lists the natural periods of vibration for the preliminary design D_0. The modal damping ratios are assumed to be 1.5 % in all six modes considered in this project.

The building's structural data are included in '*Input_ST*' folder. Table 14 lists the structural data required to analyze this example project, and their file name and path.

Table 12. Members' cross-section dimensions (unit = mm)

Members' type	Section ID	Sectional type	Depth	Width	Flange thickness	Web thickness
Bracing	1	Box/Tube	350	350	14	14
	2	Box/Tube	300	300	14	14
	3	Box/Tube	200	200	12	12
	4	Box/Tube	145	145	9	9
Column	1	Box/Tube	600	600	35	35
	2	Box/Tube	400	400	15	15
	3	Box/Tube	230	230	10	10
	4	Box/Tube	1800	1800	100	100
	5	Box/Tube	1600	1600	80	80
	6	Box/Tube	1200	1200	50	50
	7	Box/Tube	1300	1300	60	60
	8	Box/Tube	1100	1100	45	45
	9	Box/Tube	1000	1000	40	40
	10	Box/Tube	550	550	24	24
	11	Box/Tube	254	254	13	13
	12	Box/Tube	565	565	25	25
Beam	1	I/Wide Flange	261.62	146.56	11.176	6.604
	2	I/Wide Flange	259.08	102.11	10.033	6.35
	3	I/Wide Flange	251.97	202.95	13.462	8.001

Table 13. Natural periods of vibration

Mode	1st	2nd	3rd	4th	5th	6th
Natural periods [s]	4.593	4.593	4.486	1.762	1.554	1.554

Table 14. Building's structural data

Structural data	File name	Path
Members' list	*ST_members_list.mat*	C:\Project_05\Building_data
Members' properties	*ST_member_properties.mat*	
Mass matrix	*ST_mass_asc.mat*	
Influence coefficients	*ST_dif_all.mat*	
Internal forces by dead load	*ST_frames_DeadLoad.mat*	
Internal forces by super-imposed dead load	*ST_frames_SDeadLoad.mat*	
Internal forces by live load	*ST_frames_LiveLoad.mat*	
Mode shapes	*ST_ModeShapes_pd.mat*	

7.3 Aerodynamic pressure data

The example building is assumed to have open terrain exposure. The aerodynamic pressure time histories were obtained from the Tokyo Polytechnic University (TPU) high-rise building aerodynamic database
(http://www.wind.arch.t-kougei.ac.jp/system/eng/contents/code/tpu).

The length scale of the aerodynamic model was 1:400. The duration of the records was 32.8 s with sampling frequency of 1000 Hz for a total 32768 samples for each pressure tap. The mean wind speed at top of the building model during the wind tunnel tests was 11 m/s. Since a numerical integration needs a certain number of points before it stabilizes, the first 500 points of the time series are not used in the analysis.

The aerodynamic pressure coefficient data (*Cp_XXX.mat*, where *XXX* varies from '000' to '360' by in increments of 10) for this example project are included in '*Cp_data*' folder in '*Aerodynamic_data'*.

7.4 Climatological wind speed data

Structural responses to directional wind are obtained by making use of the directional wind speeds of the wind climatological database in conjunction with the response surfaces. The wind climatological database for the calculations presented in this example project is based on a wind speed dataset of 999 simulated hurricanes for 16 directions near South Carolina (Milepost 1950). The minimum hourly wind speed below which the response is no longer of interest is 20 m/s. Terrain exposures at weather station where the hurricane winds were measured and at the location of the building are open (category 'C') and suburban (category 'B'), respectively. The orientation angle of the example building is 270° clockwise from the north, that is, the front façade of the building faces north.

Peak responses are obtained for the DCIs corresponding to a 1700-year MRI. Peak inter-story drifts and accelerations of the building will be obtained from the peak response surfaces for MRI = 20 years and MRI = 10 years, respectively.

The wind climatological dataset (*Nhurr_SC(160).mat* file for the milepost 1950) included in '*Climatological_data_1*' directory, is also available at http://nist.gov/wind.

7.5 Step-by-step tutorial for DAD_ESWL

This section provides step-by-step tutorial for the use of *DAD_ESWL* software to analyze the example building subjected to wind. The tutorial follows the seven tasks (steps) of the DAD procedure shown in Fig. 1.

Step 1. Begin a new model with preliminary design D_0

Select the structural system, and determine its preliminary member sizes by using a simplified model of the wind loading (e.g., a static wind loading based on standard provisions). The structural design so achieved is denoted by D_0.

Select the structural system

a. Run **DAD_ESWL_v1p0.exe**, select the **Steel Structure,** and click the **Start** button.

Note. Please wait until the initial page is open. It might take several minutes.

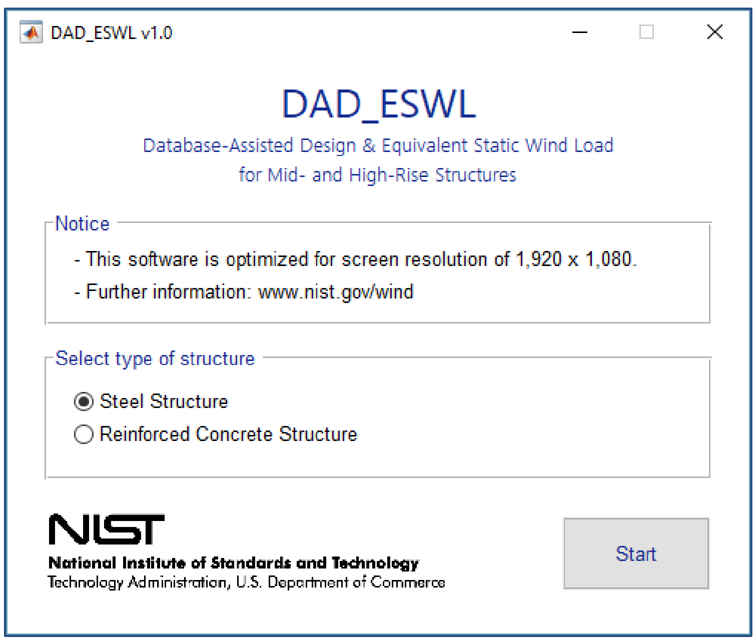


Figure 77. Structural type selection panel

The software will then display the main GUI of the **Bldg. modeling** input panel.

Building information and Analysis type panels:

a. Set the **No. of stories** to **47**.

b. Set the **Building height [m]** to **160**.

c. Set the **Building width [m]** to **40**.

d. Set the **Building depth [m]** to **40**.

e. Set the **Orientation angle [deg.]** to **270**.

f. Click the **Browse** button for **Heights of floors** section. Then select *ST_height_floors.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

g. Click the **Browse** button for **List of all members** section. Then select *ST_members_list.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

h. Click the **Browse** button for **Details of all members** section. Then select *ST_member_properties.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

i. Go to the **Analysis type** section on the right side. Select the **Second-order elastic (P-Delta)** toggle.

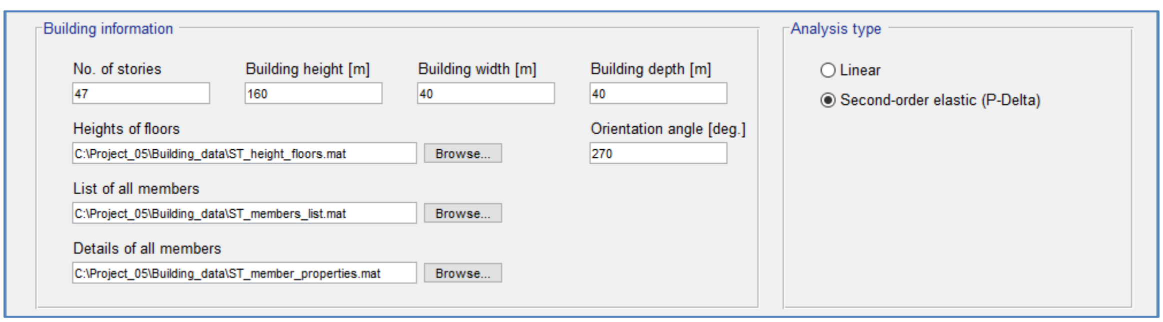


Figure 78. Building information panel

Step 2. Determine the building's structural properties

For the design D_0 (D_2 in this example): determine the building's structural properties, including the modal shapes, natural frequencies of vibration, and damping ratios, as well as the requisite influence coefficients; and develop a lumped-mass model of the structure. *P-Δ* an *P-δ* effects can be accounted for by using, for example, the effective stiffness matrix (Park and Yeo 2018).

Structural properties panel:

a. Set the **No. of modes** to **6**.

b. Set the **Modal damping ratio [%]** to **1.5 1.5 1.5 1.5 1.5 1.5** (Type **1.5** six times, successive values should be separated by an empty space).

c. Click the **Browse** button for **Mass matrix** section. Then select *ST_mass_asc.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

d. Select the **Input analysis results from arbitrary FE software**. If you selected the **Second-order elastic (P-Delta)** option, the **Use OpenSees for calculation** section will not be activated.

e. Click the **Browse** button for **Influence coefficients** section. Then select *ST_dif_all.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

f. Click the **Browse** button for **Internal forces due to dead load** section. Then select *ST_frames_DeadLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

g. Click the **Browse** button for **Internal forces due to super-imposed dead load** section. Then select *ST_frames_SDeadLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

h. Click the **Browse** button for **Internal forces due to live load** section. Then select *ST_frames_LiveLoad.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

i. Click the **Browse** button for **Mode shapes** section. Then select *ST_ModeShapes_pd.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

j. Set the **Modal periods [s]** to **4.066 4.066 3.960 1.567 1.412 1.412** (each value should be separated by an empty space).

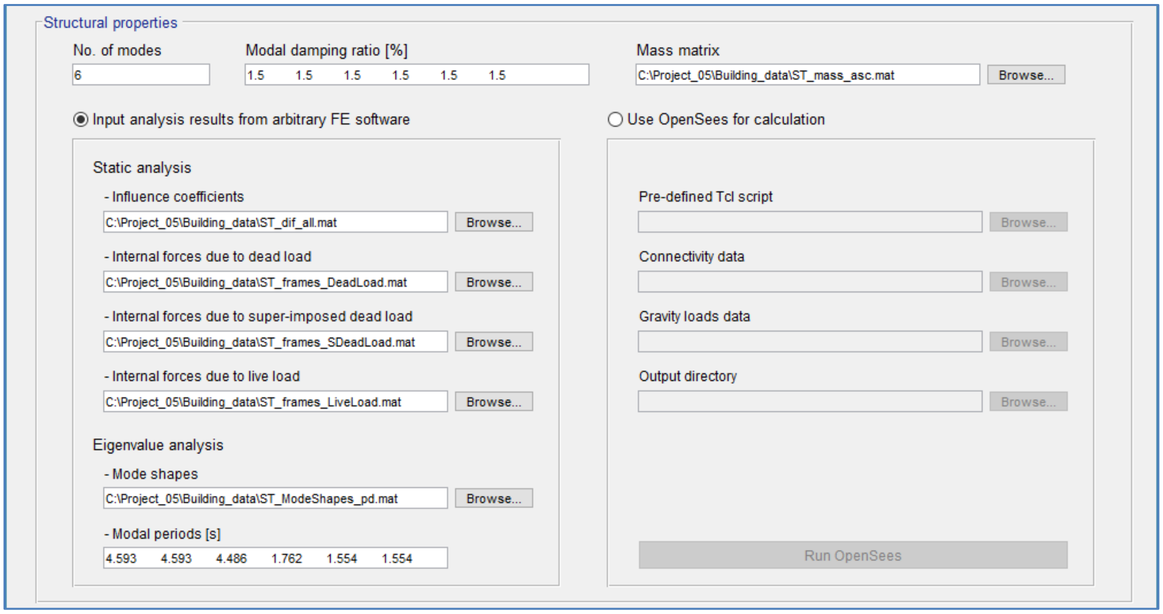


Figure 79. Structural properties panel

k. Move on to the **Wind loads** panel by clicking the **Wind loads** button below.

Step 3. Determine aerodynamic wind loads

From the time histories of simultaneously measured pressure coefficients, determine the time histories of the randomly varying aerodynamic loads induced at all floor levels by mean wind speeds from, depending upon location, 20 m/s to 80 m/s in increments of 10 m/s, say, with directions from $0° \leq \theta < 360°$ typically in increments of 10°, say.

Wind tunnel test / CWE data panel:

a. Set the **Model length scale [Prototype/Model]** to **400**.

b. Set the **Reference wind speed at rooftop elevation of the building model [m/s]** to **11.0005**.

c. Set the **Wind directions [deg.]** to **0:10:360**.

d. Set the **Sampling rate [Hz]** to **1000**.

e. Set the **No. of sampling points [points]** to **32768**.

f. Set the **Discarded initial portion of response time series [points]** to **500**.

Move onto the **Floor wind loads at model scale [N and N.m]** section.

g. Select the **Calculate floor wind loads from pressures measured in taps on building model façade**. The input sections below will then be activated.

h. Click the **Browse** button for **Time-series of pressure coefficients** section. Then select *Cp_data* directory from *Aerodynamic_data* folder in the default directory (C:\Project_05). In the *Cp_data* directory, the pressure coefficient data files, *Cp_XXX.mat* where *XXX* varies from '000' to '360' by in increments of 10, must be included.

i. Click the **Browse** button for **Pressure tap identification** section. Then select *tap_loc.mat* file from *Aerodynamic_data* folder in the default directory (C:\Project_05).

j. Click the **Browse** button for **Pressure tap coordinates** section. Then select *tap_coord.mat* file from *Aerodynamic_data* folder in the default directory (C:\Project_05).

k. Select **Cubic** in the **Select interpolation method** section, then click the **Select** button.

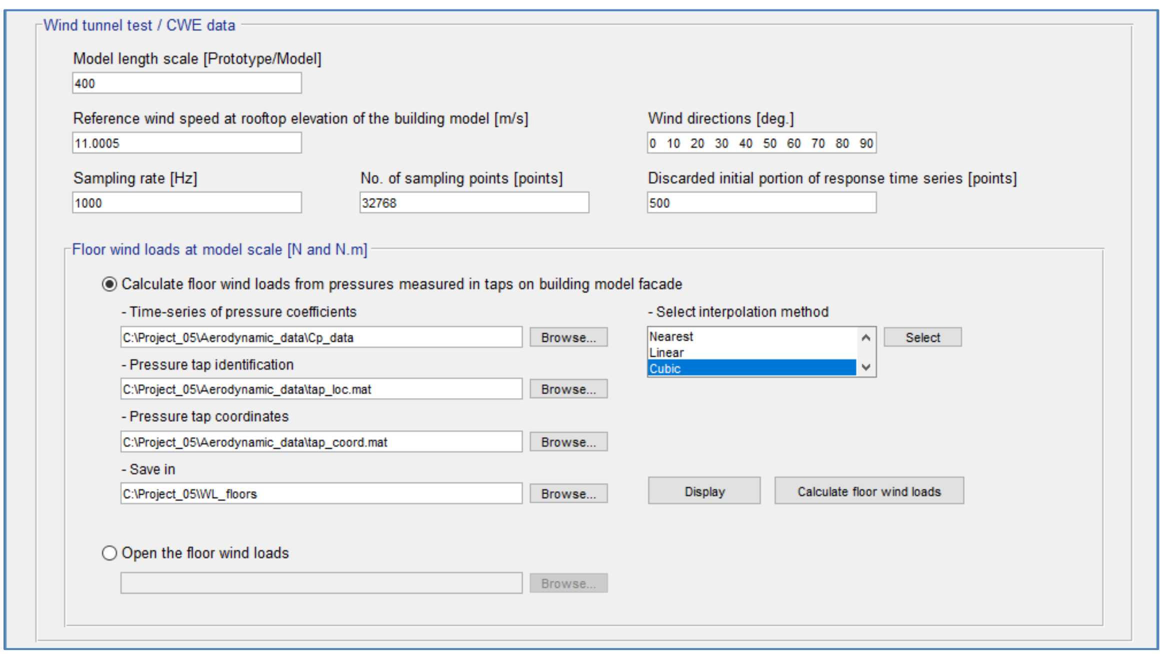


Figure 80. Wind tunnel test / CWE data panel

Note 1. Mandatory input files for the pressure data (*Cp_XXX.mat*), tap location (*tap_loc.mat*), and tap coordinates (*tap_coord.mat*) must be created in advance from wind tunnel test or CFD analysis. The formats and structures required for those input files are described in the User's Manual in NIST Technical Note 2000 (Section 4.2).

Note 2. You can check the wind pressure information (i.e., location of pressure taps, time-series of the pressure coefficients at each tap, pressure contour on each façade of building model) by clicking the **Display** button below. Please refer to the User's Manual in NIST Technical Note 2000 for details.

l. Click the **Calculate floor wind loads** button. The software will be starting the calculation of the floor wind loads automatically. A pop-up window to show the calculation progress will appear.

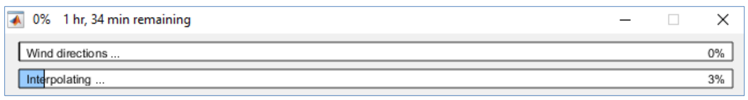


Figure 81. Computation of floor wind loads

m. During the calculation, the **Calculate floor wind loads** button will become inactive, and show a message that **'Calculating wind loads … busy'**. The calculation might take from minutes to hours depending on the size of the pressure time-series, the number of taps, and the interpolating method the users selected. After the calculation, a message **'Done'** will be displayed, and you can proceed to the next stage.

Note. The floor wind load data for each wind direction will be saved in the new folder named *WL_floors* in the default directory (C:\Project_05).

Wind speed range panel:

a. Set the **Wind speeds for response surfaces [m/s]** to **20:10:80**.

Lower limit requirement panel:

a. Select the **ASCE 7-based overturning moments [N.m]** toggle. Click the **Browse** button and then select *moment_ovtn_ASCE.mat* file from *Building_data* folder in the default directory (C:\Project_05).

b. Click the **80 %** check box on the **Limiting value** section.

Figure 82. Wind speed range and lower limit requirement panel

b. Move on to the **Resp. surface** panel by clicking the **Resp. surface** button below.

Step 4-6. Perform dynamic analysis and construct response surfaces for wind effects

Perform the dynamic analysis based on the lumped-mass model of the structure to obtain the time histories of the inertial forces induced by the respective aerodynamic loads, and the effective wind-induced loads consisting of the sums of the aerodynamic and inertial force time histories. The lateral loads are determined at all floor levels of the building. Construct the response surfaces of the peak combined effects (e.g., DCIs, inter-story drift ratio, accelerations) as functions of wind speed and direction.

Load combination cases panel:

a. Set the **Dead load (D)** to **1.2**.

b. Set the **Super-imposed dead load (Ds)** to **1.2**.

c. Set the **Live load (L)** to **1**.

d. Click the **Add** button. The list box above the button will display the load combination case LC1 based on the load factors you set. If your inputs are wrong, click the **Reset** button, then the list box will be empty. Re-input the load factors from the step 'a'.

e. Create LC2 in the same way. The load factors for **D**, **Ds**, and **L** are **0.9**, **0.9**, and **0**, respectively.

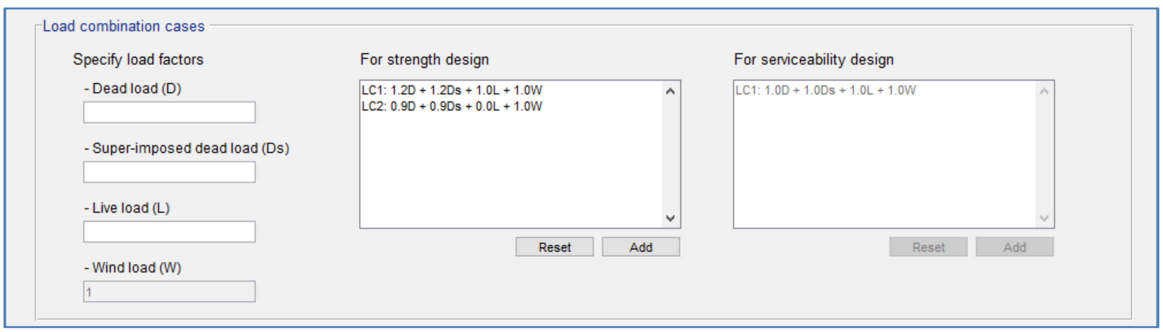


Figure 83. Load combination cases panel

Calculation options panel:

a. Select the **DAD** toggle.

b. Click the **Multiple Points-In-Time approach** check box. Set the points to **30**.

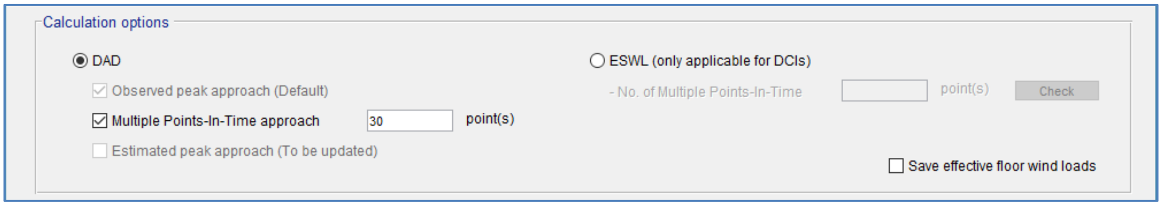


Figure 84. Calculation options panel

Response surface panel:

For the **Demand-to-Capacity Index (DCI)** section,

a. Click the **Browse** button for **Specify members of interest** section. Then select *ST_member_selected_simple.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

Note) The selected members of interest in this example are three columns, member ID = 1, 10, and 20, out of 8555 members.

b. Click the **Browse** button for **Save as** section. Then type **'DCI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_05).

For the **Inter-story drift ratio** section,

c. Click the **Browse** button for **Specify column lines of interest** section. Then select *ST_Interstory_Drift_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

d. Click the **Browse** button for **Save as** section. Then type **'InDr'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_05).

For the **Accelerations** section,

e. Click the **Browse** button for **Specify column lines of interest** section. Then select *ST_Acceleration_Input.mat* file from *Building_data* folder in the default directory (C:\ Project_05).

f. Click the **Browse** button for **Save as** section. Then type **'Acc'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_05).

g. Click the **Compute response surface** button. The pop-up window will then appear to show the progress of the calculation (Fig. 90).

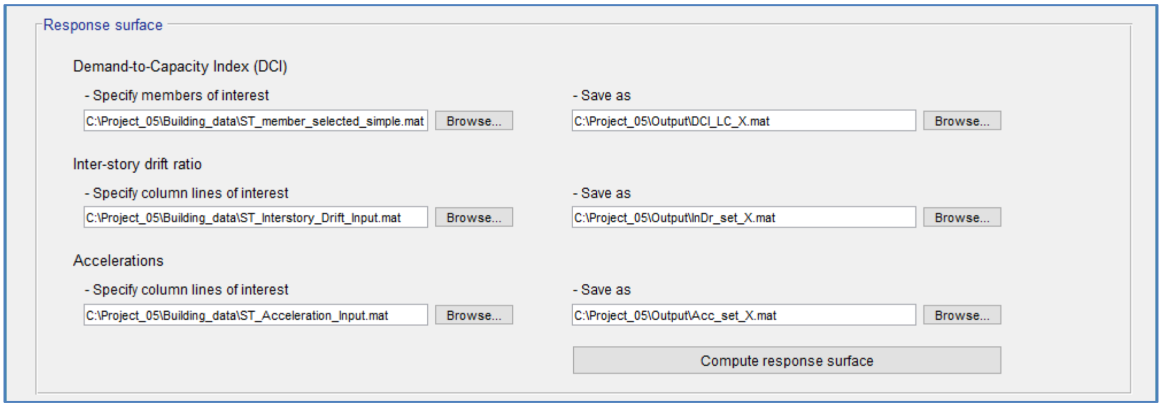


Figure 85. Response surface panel

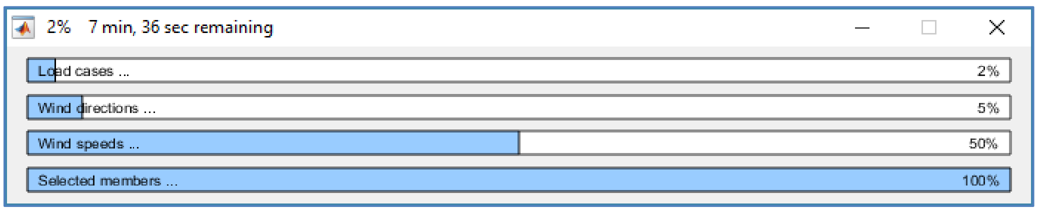


Figure 86. Progress bar

i. Please wait until the calculation is done. This might take several minutes.

j. Once the calculation is done, the progress bar will be automatically disappeared. Then move onto the **Wind effects** panel by clicking the **Wind effects** button below.

Step 7. Determine design wind effects with specified MRIs

Use the information contained in the response surfaces and in the matrices of directional wind speeds at the site to determine, by accounting for wind directionality, the design DCIs with the specified design MRI for the cross sections of interest.

Wind climatological data panel:

a. Select the **NIST Hurricane wind speed data** toggle.

b. Click the **Browse** button for **Specify the data file** section. Then select *Nhurr_SC(160).mat* file from the *Climatological_data_1* directory from the default directory (C:\ Project_05).

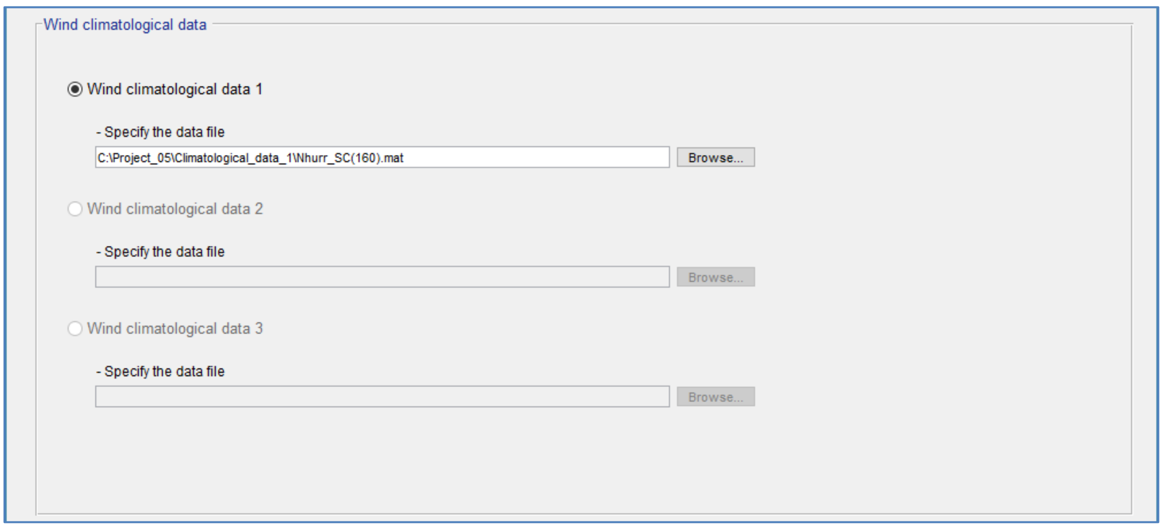


Figure 87. Wind climatological data panel

Design responses for specified MRIs panel:

a. Set the **MRIs for demand-to-capacity index [years]** to **1700**.

b. Click the **Browse** button for **Save as** section. Then type **'DCI_MRI'** as a new filename for DCI results in *Output* folder in the default directory (C:\ Project_05).

c. Set the **MRIs for inter-story drift ratio [years]** to **20**.

d. Click the **Browse** button for **Save as** section. Then type **'InDr_MRI'** as a new filename for inter-story drift results in *Output* folder in the default directory (C:\ Project_05).

e. Set the **MRIs for acceleration [years]** to **10**.

f. Click the **Browse** button for **Save as** section. Then type **'Acc_MRI'** as a new filename for acceleration results in *Output* folder in the default directory (C:\Project_05).

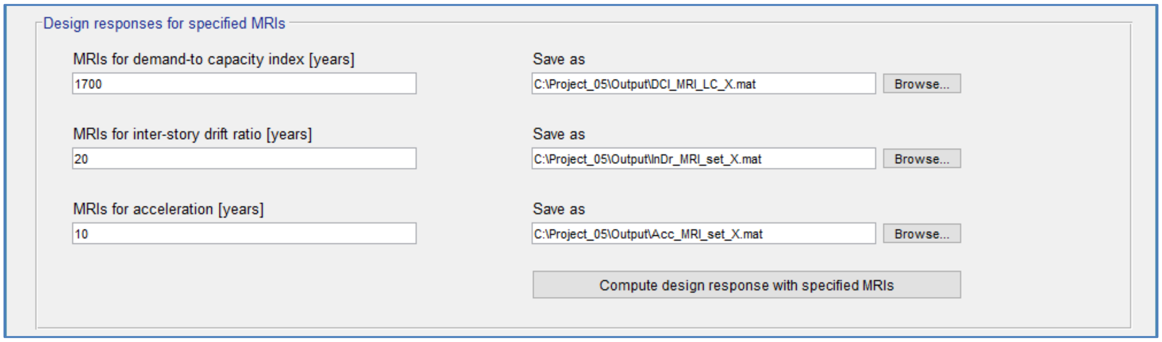


Figure 88. Design responses for specified MRIs panel

g. Click the **Compute design response with specified MRIs** button. The pop-up window will appear to check whether the response surface was constructed for the entire set of wind directions (Fig. 89).

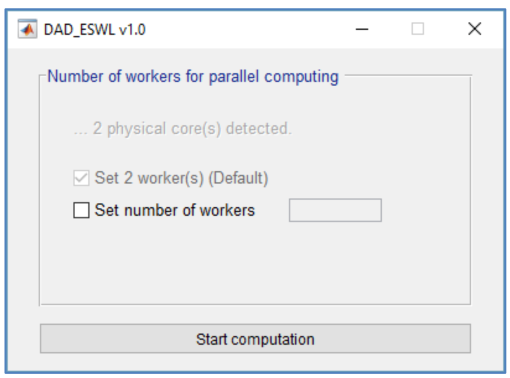


Figure 89. Parallel computing setting dialog

h. After setting the number of workers, click the **Start computation** button. The progress bar will then appear. Please wait until the calculation is done. This might take several minutes.

i. Once the calculation is done, the progress bar will be automatically disappeared. Move onto the **Results & Plots** panel by clicking the **Results & Plot** button below.

7.6 Displaying analysis results for DAD_ESWL

This section provides a tutorial for displaying the analysis results in the software.

Results & Plots panel:

a. Select the **Demand-to-Capacity Index (DCI)** toggle.

b. Select **Combo max. case** from the list box on the **Load case** section. Click the **Check** button.

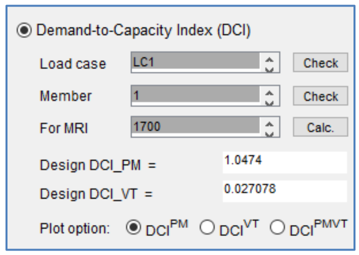


Figure 90. Demand-to-Capacity Index (DCI) section

c. Select **1** from the list box on the **Member** section. Click the **Check** button.

d. Select **1700** from the list box on the **For MRI** section. Click the **Calc** button.

e. Check the values displayed on the boxes below. These values are the peak DCIs with 1700 years-MRI for the envelopment of the peak DCI results from the two load combinations, LC1 and LC2.

f. In the **Plot option** section, click the **DCI^{PM}** toggle to display the response surface for the DCI^{PM} of the selected member.

g. Click the **Plot response surface** button below the figure displaying area. Then check the response surface (Fig. 92).

Note) If you click the **Plot response surface** button with the **Combo max. case** selected in the **Load case** section, an error message will appear as shown in Fig. 76. Plotting the response surface for the combination maximum case is not supported.

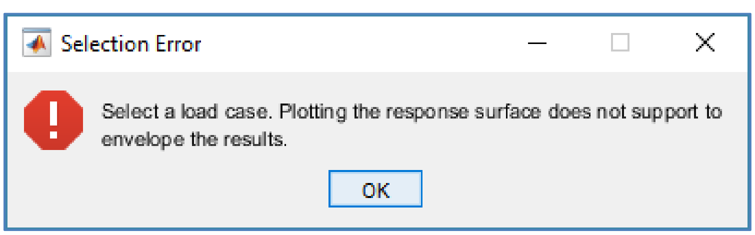


Figure 91. Error message for plot response surface

h. Click the **Plot design response** button below the figure displaying area. Then check the peak DCIs depending upon the MRIs (Fig. 98).

i. If you want to edit the figure currently displayed, e.g., rotating a viewing-angle of the figure, moving the objects of figures like legend and title, or saving the figure to local hard drive of your computer, click the **Edit figure** button.

Note 1. For the other wind effects, i.e., **Overturning moment**, **Inter-story drift ratio**, and **Acceleration**, do the same step from 'a' to 'i'. To see a detailed function for each selection, please refer to the User's Manual in NIST Technical Note 2000.

Note 2. For details about the output files you saved in the default folder, '*Output*', please refer to the User's Manual in NIST Technical Note 2000.

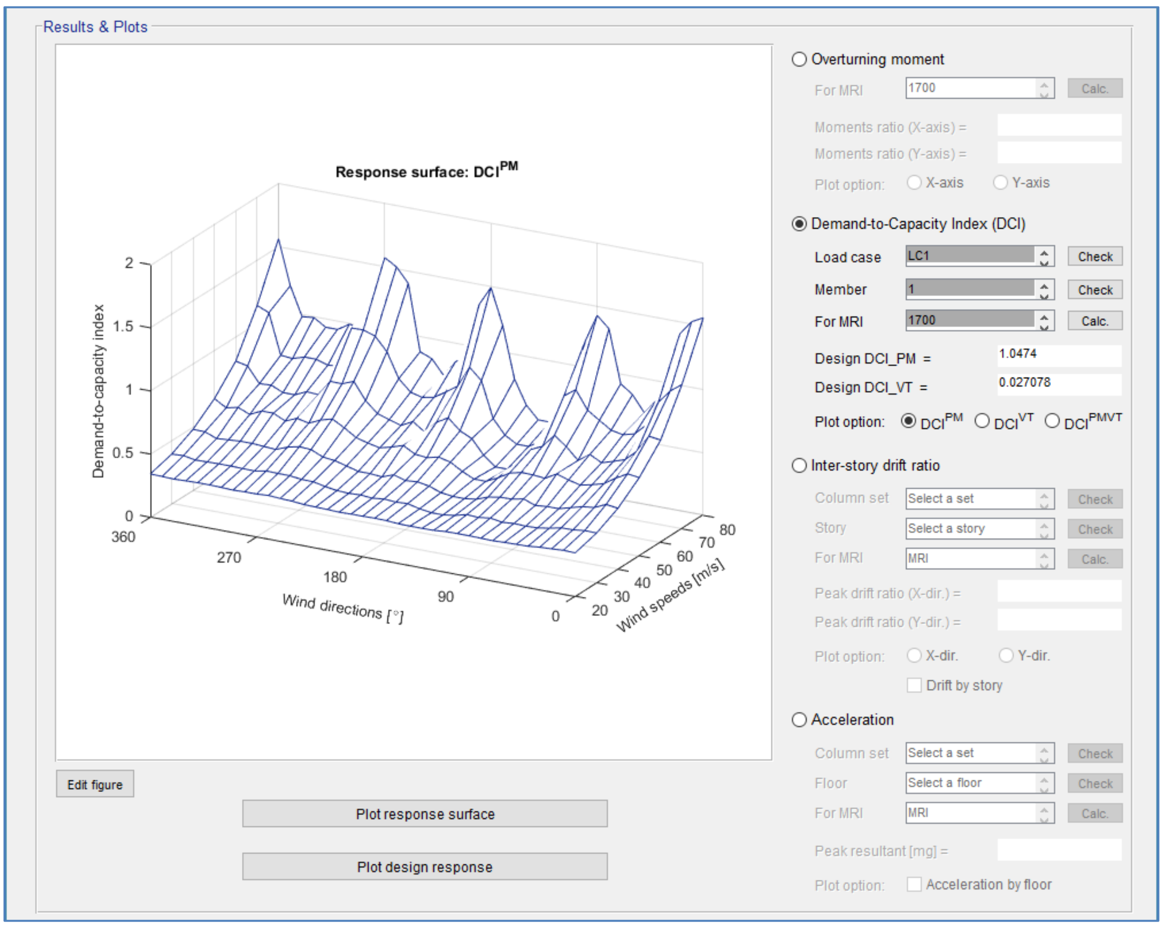


Figure 92. Results & Plots panel: Plot response surface

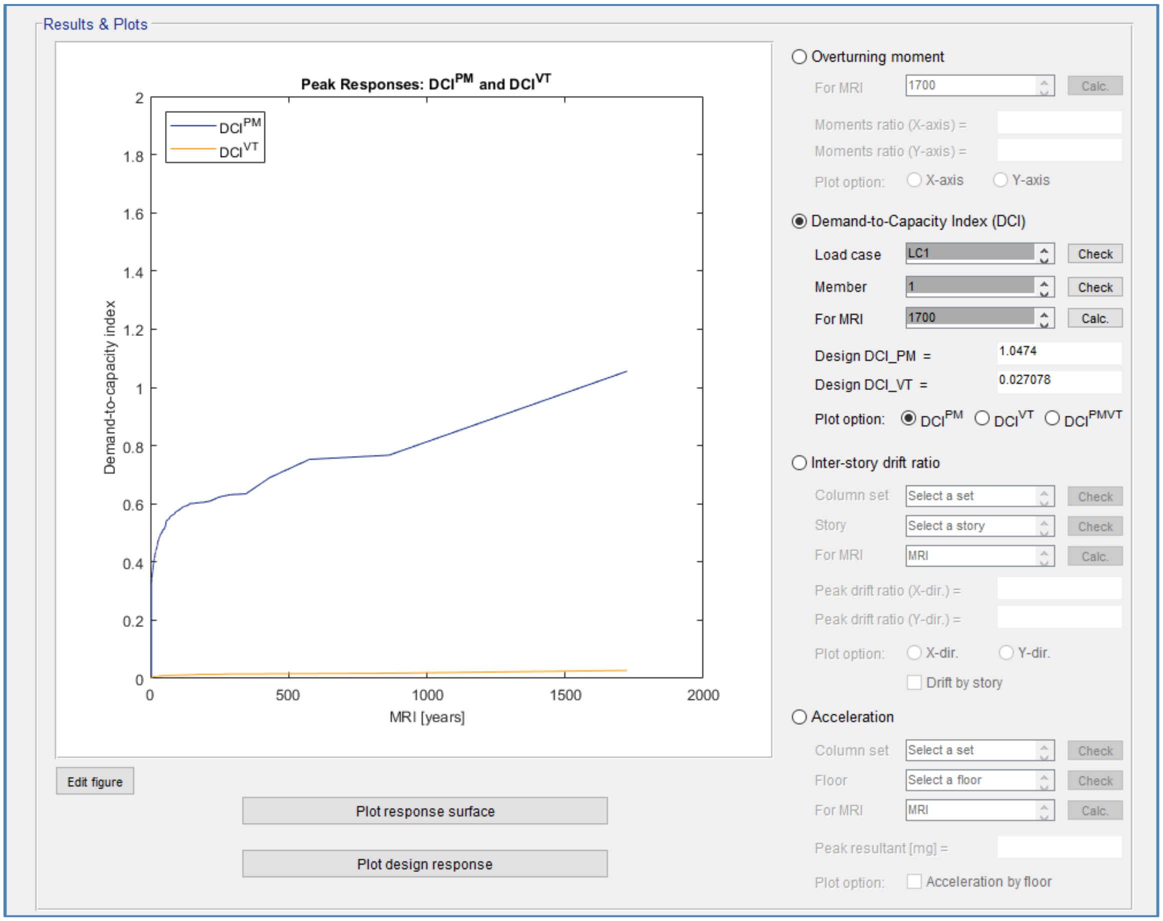


Figure 93. Results & Plots panel: Plot design response

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