EVW Tool Examples

Examples included in this document are based on the *user manual* provided on EVW Application Webpage.

Example 1: The SAC 3-story Los Angeles Building, Hazard Level 2/50 (3LA250)

Building properties and loadings are adopted from SAC examples provieded in *State of the Art Report on Systems Performance of Steel Moment Frames Subject to Earthquake Ground Shaking* (FEMA335C [4]). Building floor plans and elevations are shown in Figure 1. Only the *North-South* direction is taken into consideration. Layout of the moment resisting building for the LA building is shown in Figure 2. The loading used for the analysis of the frames is based on the details given in FEMA335C [4], which result in the following floor load distribution (steel weight is assumed as 13 psf for all designs):

Floor dead load for weight calculations: 96 psf

Floor dead load for mass calculations: 86 psf

Roof dead load excluding penthouse: 83 psf

Penthouse dead load: 116 psf

Reduced live load per floor and for roof: 20 psf

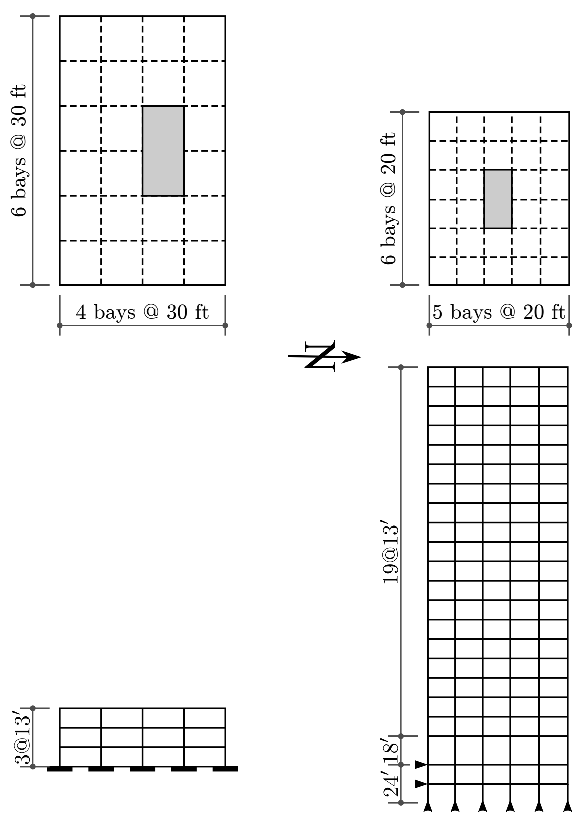
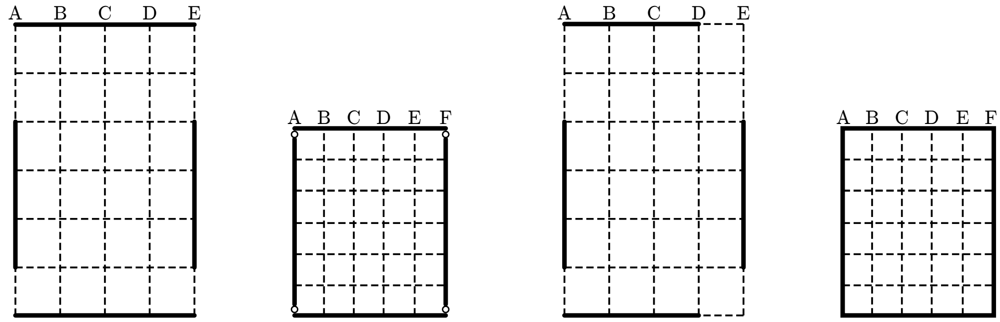


Figure 1: Floor plans and elevations for model buildings [4].



(a) Seattle, 3-story (b) Seattle, 20-story (c) LA, 3-story (d) LA, 20-story

Figure 2: Floor plans showing layout of moment-resisting frames for LA and Seattle model buildings [4].

Properties of the 3-story building located in LA for the hazard level of 2/50 are tabulated in Table 1. These properties are based on the location, geometry and function of the building as described in FEMA335C [4].

Table 1: 3-story building properties, Los Angeles, hazard level: 2/50 (3LA250).

Item	Value	Source
Basic wind speed at reference height in exposure C	95 mph	Fig. 26.5-1 ASCE 7-16
Type of exposure	B	user spec
h Building height	39 ft (11.87 m)	user spec
B Building width	180 ft (54.79 m)	user spec
L Building depth	120 ft (36.53 m)	user spec
n_1 Building natural frequency	0.62 Hz	analysis or rational approximation[1)]
ζ Damping ratio	0.02	rational assignment[2)]
C_{fx} Mean along-wind force coefficient	1.3	
β Mode exponent	1.0	user spec
Building density	1.03 slugs/ft^3	bldg function

1) for approximate natural frequencies see section 26.11.2 and C26.11 of the ASCE 7-16. For this example, since the building are designed and the properties of the building elements are known, the natural frequency is accurately calculated.

2) recommended values for damping ratio can be found in Table 11.2.1, Dynamics of Structures by Chopra, 4th ed. [3]

Procedure

In order to use the EVW app, input forces and building properties need to be known. For Gust wind speed, gust-effect factor should be computed based on the location and function of the building according to the chapter 26 of the ASCE7-16 [2]. This is shown in Table 2.

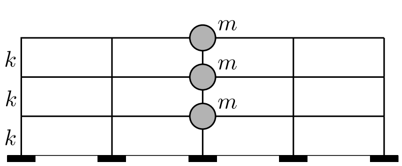
Table 2: Gust-effect factor, 3LA250.

Item	Value	Source
FLEXIBLE BUILDING (all n_1)		
$\bar{z}$ Effective structure height	23.4 ft	$0.6h$ (26.11.4 ASCE 7-16)
$I_{\bar{z}}$ Turbulence intensity at eff. height	0.318	eq. 26.11.7 ASCE 7-16
$L_{\bar{z}}$ Turbulence length scale at eff. height	285.4 ft	eq. 26.11.9 ASCE 7-16
V Basic wind speed	95 mph	Fig. 26.5-1 ASCE 7-16
β Damping ratio	0.02	rational assignment
$\bar{\alpha}$ Power law exponent of mean wind speed profile	0.25	Table 26.11-1 ASCE 7-16
$\bar{b}$ Gust factor 1/F at 10 m	0.45	Table 26.11-1 ASCE 7-16
$\bar{V}_{\bar{z}}$ Mean wind speed at effective height	57.5	eq. 26.11-16 ASCE 7-16
N_1 Reduced natural frequency	3.08	eq. 26.11-14 ASCE 7-16
R_n Resonance response factor for n	0.069	eq. 26.11-13 ASCE 7-16
η_h Vertical decay parameter	1.934	eq. 26.11-5 ASCE 7-16
η_B Cross-wind decay parameter	8.928	eq. 26.11-5 ASCE 7-16
η_L Along-wind decay parameter	19.926	eq. 26.11-5 ASCE 7-16
R_h Resonant factor for h	0.386	eq. 26.11-15a ASCE 7-16
R_B Resonant factor for B	0.106	eq. 26.11-15a ASCE 7-16
R_L Resonant factor for L	0.049	eq. 26.11-15a ASCE 7-16
R^2 Resonant response (squared)	0.078	eq. 26.11-12 ASCE 7-16
g_R Resonant peak factor	4.074	eq. 26.11-11 ASCE 7-16
G_f Gust-effect factor	1.162	eq. 26.11-10 ASCE 7-16

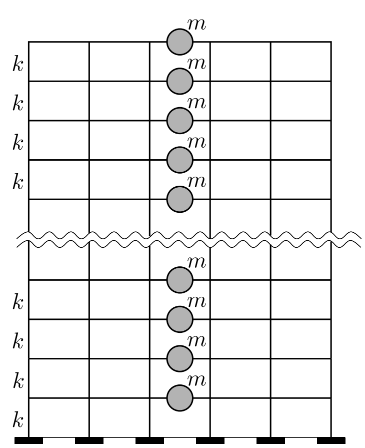
Therefore, Gust wind speed in mph is:

$G_f \times C = 1.162 \times 95 = \boxed{110.4}$

For earthquake analysis and stick model, buildings can be idealized with mass concentrated at one location for each floor (m) and stiffness of each floor (k) represents the lateral stiffness of the moment resisting frames and/or walls in the direction considered. Idealized building mass and stiffness of the 3-story and 20-story buildings are shown in Figure 3.



(a) 3-story building



(b) 20-story building

Figure 3: Idealized building mass and stiffness

Stiffness Calculation:

For the exact calculation of the stiffness of any structure, properties and geometry of beams, columns, walls and slabs and lateral systems need to be known. However, these information are not available prior to design. Therefore, the stiffness is usually estimated. For a single degree of freedom (SDOF) frame structure (Figure 4), the lateral stiffness for the two extreme cases are as follows [3]:

$$k = \sum_{\text{columns}} \frac{12EI_c}{h^3} \qquad \text{if the beam is rigid; i.e., } EI_b = \infty$$

$$k = \sum_{\text{columns}} \frac{3EI_c}{h^3} \qquad \text{for a beam with no stiffness; i.e., } EI_b = 0$$

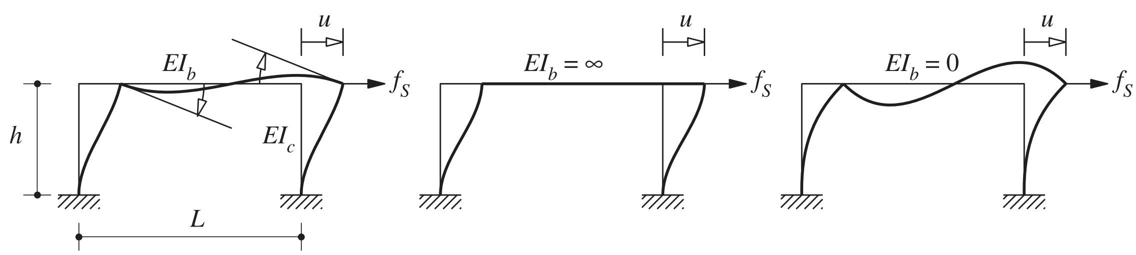


Figure 4: Single frame idealized as SDOF [3]

In the equations above, E is the modulus of elasticity of steel and I_c and I_b are the moments of inertia of the column and beam respectively.

To determine the lateral stiffness of the frame in Figure 4 considering the real stiffness of the beam, standard procedures of static structural analysis can be used (equation below). This procedure is explained in details by Chopra [3].

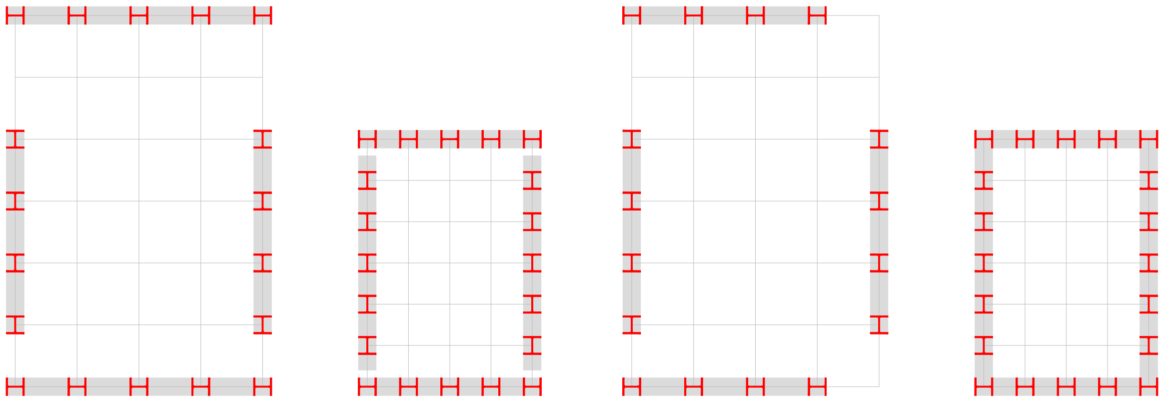
$$k = \frac{24RI_c}{h^3}\frac{12\rho + 1}{12\rho + 4}$$

where ρ is the beam-to-column stiffness ratio and expressed as

$$\rho = \frac{EI_b/L}{2EI_c/h}$$

For MDOF structures the stiffness of the frame can be determined using numerical analysis. Lateral load can be applied to the top of the story of interest and then the displacement caused by the applied load will be measured. Then the accurate lateral stiffness can be calculated from the displacement caused by the lateral load.

In the SAC examples included in this document, both extreme values of stiffness assuming $EI_b = \infty$ and $EI_b = 0$ and the actual EI_b are considered. Numerical analysis employing SAP2000 [6] software package is used to account for the stiffness of the horizontal members for each story. Table 3 shows the story stiffness of the 3-story buildings in Seattle and Los Angeles. Actual EI_b values shown in the Table 3 are based on the column and beam cross-sections provided in the FEMA335C [4]. Wherever, the column section is changing the in the mid-height of the story, the smaller cross-section is considered for the story stiffness calculations. The orientation of the column cross-sections for the moment frames are shown in Figure 5. Note that only the stiffness of the lateral resisting elements are taken into consideration for each story stiffness and lateral stiffness of the gravity columns are ignored. Results of the story stiffness calculations for the 20-story buildings located in Seattle and Los Angeles are shown in Table 4. The modulus of elasticity, E, and yield strength, f_y, of steel are assumed to be 29000 ksi and 60 ksi, respectively. Values of moment of inertia for the standard steel sections given are available in AISC Steel Construction Manual [1].



(a) Seattle, 3-story **(b)** Seattle, 20-story **(c)** LA, 3-story **(d)** LA, 20-story

Figure 5: Orientation of the columns in the moment-frames for the 3- and 20-story SAC buildings. (*Note that column and beam sections for each design are available in FEMA335C [4]*).

Table 3: Story stiffness for the 3-story buildings.

Seattle				Los Angeles			
Story	Stiffness, k/in.			Story	Stiffness, k/in.		
	$EI_b = \infty$	actual EI_b	$EI_b = 0$		$EI_b = \infty$	actual EI_b	$EI_b = 0$
1	5,097	2,918	1,274	1 & 2	2,834	1,593	709
2,3	1,742	854	435	3	2,834	1,161	709

Table 4: Story stiffness for the 20-story buildings.

Seattle				Los Angeles			
Story	Stiffness, k/in.			Story	Stiffness, k/in.		
	$EI_b = \infty$	actual EI_b	$EI_b = 0$		$EI_b = \infty$	actual EI_b	$EI_b = 0$
1	4,434	2,319	1,108	1	3,427	2,378	856
2 - 5	11,769	5,142	2,942	2 - 4	9,527	4,235	2,381
6 - 8	10,560	4,756	2,640	5 - 10	7,714	3,746	1,928
9 - 10	10,560	4,238	2,640	11 - 13	6,284	3,172	1,571
11 - 12	8,748	3,600	2,104	14 - 16	4,323	2,414	1,080
13 - 15	8,748	2,925	2,104	17 - 18	3,127	1,801	781
16 - 17	5,689	2,202	1,422	19	2,353	1,299	588
18 - 20	4,422	1,856	1,105	20	2,353	1,153	588

Thus, for this example, the input forces and building properties used in the EVW app are shown in table below. For stiffness value, actual EI_b are used.

Table 5: Input forces and building properties (3LA250).

Input Forces		
Earthquake:	Input motion	Northridge
	Scale factor	0.79
Wind:	Exposure category	B
	Gust wind speed	110.4 mph
	Seed	100
Building Properties		
	Number floor	3
	Building weight	6503.1 k
	shape	Rectangular
	Height	468 in.
	Width	2160 in.
	Length	1440 in.
	Drag coefficient	1.3
	Story stiffness	see Table 3
	Damping ratio	0.02
Disable PDelta effects		

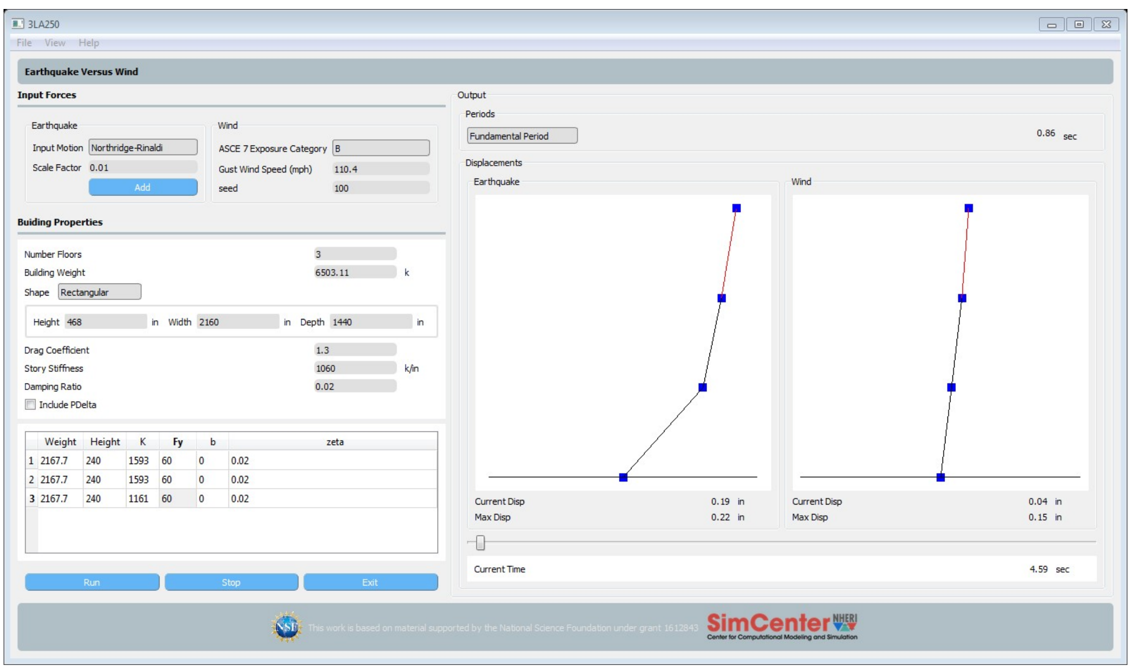


Figure 6: Program display after inputs entered for building 3LA250.

Following figures show some of the graphics available in the tool.

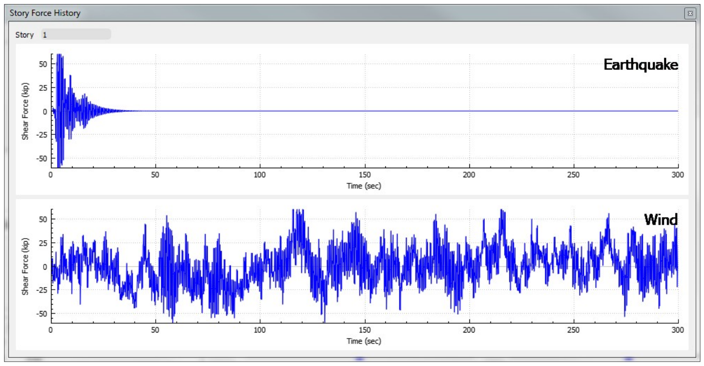


Figure 7: Floor displacement history, 3LA250, third floor.

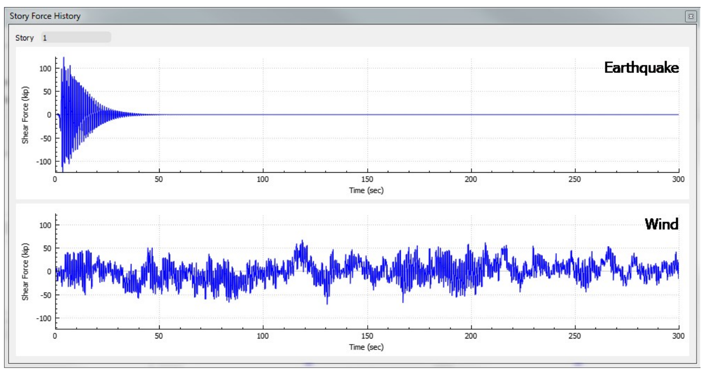


Figure 8: Story force history, 3LA250, first floor.

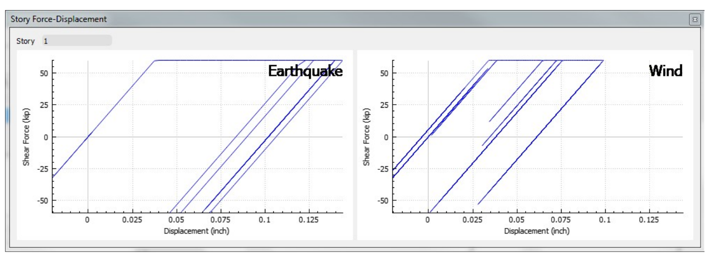


Figure 9: Story force displacement, 3LA250, first floor.

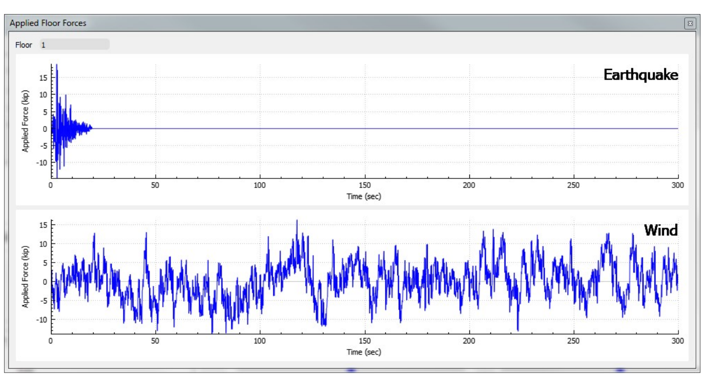


Figure 10: Applied floor forces, 3LA250, first floor.

Example 2: The SAC 3-story Seattle Building, Hazard Level 2/50 (3SE250)

Properties of the 3-story building located in Seattle for the hazard level of 2/50 are tabulated in Table 6. These propteries are based on the location, geometry and function of the building as described in FEMA335C [4]. Floor plans, elevations and plans of moment-resisting frames for the Seattle model building are shown in Figures 1 and 2.

Table 6: 3-story building properties, Seattle, hazard level: 2/50 (3SE250).

Item	Value	Source
Basic wind speed at reference height in exposure C	98 mph	Fig. 26.5-1 ASCE 7-16
Type of exposure	B	user spec
h Building height	39 ft (11.87 m)	user spec
B Building width	180 ft (54.79 m)	user spec
L Building depth	120 ft (36.53 m)	user spec
n_1 Building natural frequency	2.20 Hz	analysis or rational approximation[1)]
ζ Damping ratio	0.02	rational assignment[2)]
C_{fx} Mean along-wind force coefficient	1.3	
β Mode exponent	1.0	user spec
Building density	1.03 slugs/ft^3	bldg function

1) for approximate natural frequencies see section 26.11.2 and C26.11 of the ASCE 7-16. For this example, since the building are designed and the properties of the building elements are known, the natural frequency is accurately calculated.

2) recommended values for damping ratio can be found in Table 11.2.1, Dynamics of Structures by Chopra, 4th ed. [3]

Procedure

Same as the previous example, in order to use the EVW app, input forces and building properties need to be known. Gust-effect factor is calculated as shown in Table 7.

Table 7: Gust-effect factor, 3LA250.

Item	Value	Source
FLEXIBLE BUILDING $(alln_1)$		
$\bar{z}$ Effective structure height	23.4 ft	0.6h (26.11.4 ASCE 7-16)
$I_{\bar{z}}$ Turbulence intensity at eff. height	0.318	eq. 26.11.7 ASCE 7-16
$L_{\bar{z}}$ Turbulence length scale at eff. height	285.4 ft	eq. 26.11.9 ASCE 7-16
V Basic wind speed	98 mph	Fig. 26.5-1 ASCE 7-16
β Damping ratio	0.02	rational assignment
$\bar{\alpha}$ Power law exponent of mean wind speed profile	0.25	Table 26.11-1 ASCE 7-16
$\bar{b}$ Gust factor 1/F at 10 m	0.45	Table 26.11-1 ASCE 7-16
$\bar{V}_{\bar{z}}$ Mean wind speed at effective height	59.4	eq. 26.11-16 ASCE 7-16
N_1 Reduced natural frequency	10.58	eq. 26.11-14 ASCE 7-16
R_n Resonance response factor for n	0.031	eq. 26.11-13 ASCE 7-16
η_h Vertical decay parameter	6.650	eq. 26.11-5 ASCE 7-16
η_B Cross-wind decay parameter	30.691	eq. 26.11-5 ASCE 7-16
η_L Along-wind decay parameter	68.498	eq. 26.11-5 ASCE 7-16
R_h Resonant factor for h	0.139	eq. 26.11-15a ASCE 7-16
R_B Resonant factor for B	0.032	eq. 26.11-15a ASCE 7-16
R_L Resonant factor for L	0.015	eq. 26.11-15a ASCE 7-16
R^2 Resonant response (squared)	0.004	eq. 26.11-12 ASCE 7-16
g_R Resonant peak factor	4.373	eq. 26.11-11 ASCE 7-16
G_f Gust-effect factor	0.81	eq. 26.11-10 ASCE 7-16

Therefore, Gust wind speed in mph is:

$$G_f \times C = 0.81 \times 98 = \boxed{79.4}$$

Thus, input forces and building properties used in the EVW app are shown in table below:

Table 8: Input forces and building properties (3SE250).

Input Forces		
Earthquake:	Input motion	Northridge
	Scale factor	0.22
Wind:	Exposure category	B
	Gust wind speed	79.4 mph
	Seed	100
Building Properties		
	Number floor	3
	Building weight	6503.1 k
	shape	Rectangular
	Height	468 in.
	Width	2160 in.
	Length	1440 in.
	Drag coefficient	1.3
	Story stiffness	see Table 3
	Damping ratio	0.02
Enable PDelta effects		

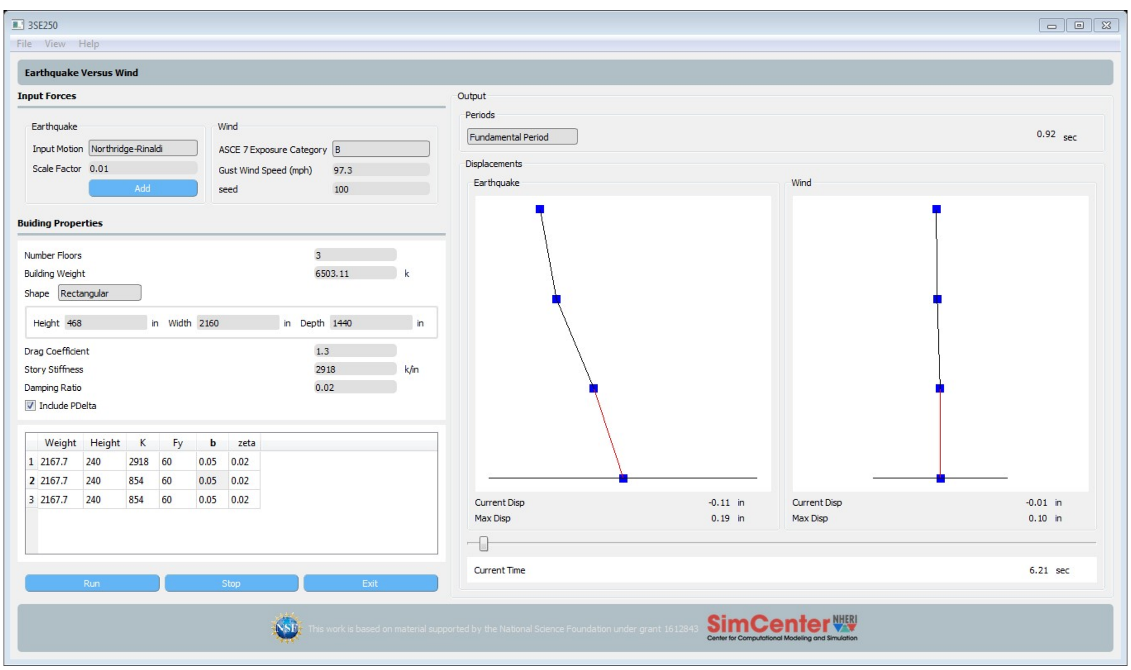


Figure 11: Program display after inputs entered for building 3SE250.

Following figures show some of the graphics available in the tool.

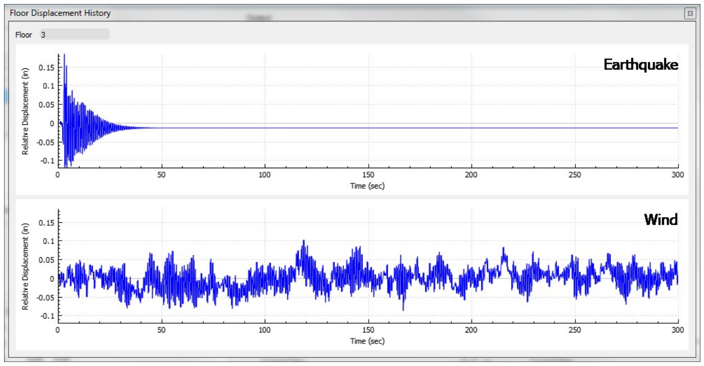


Figure 12: Floor displacement history, 3SE250, third floor.

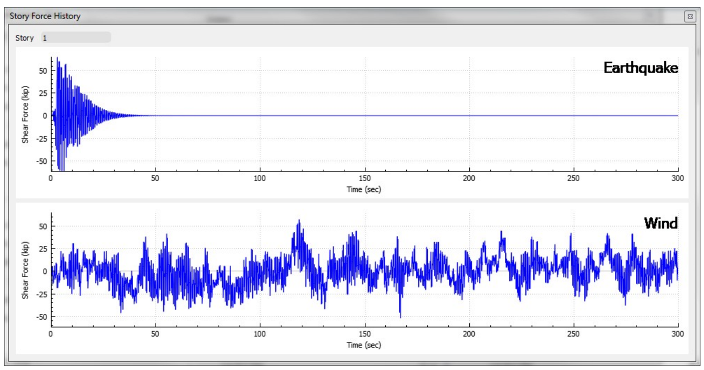


Figure 13: Story force history, 3SE250, first floor.

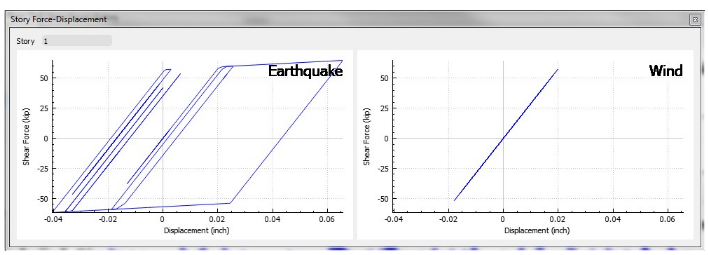


Figure 14: Story force displacement, 3SE250, first floor.

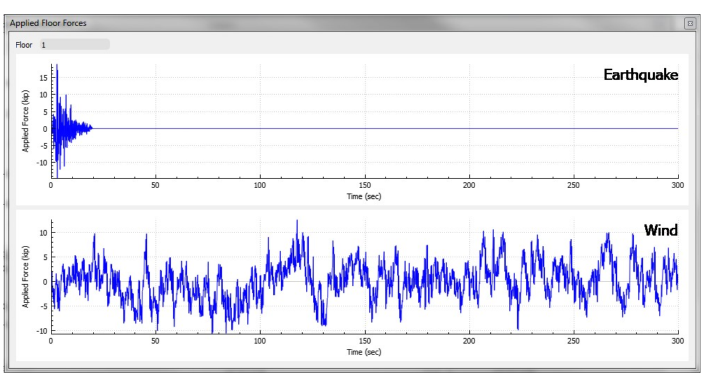


Figure 15: Applied floor forces, 3SE250, first floor.

Example 3: The SAC 20-story Los Angeles Building, Hazard Level 2/50 (20LA250)

Properties of the 20-story building located in Los Angeles for the hazard level of 2/50 are tabulated in Table 9. Floor plans, elevations and plans of moment-resisting frames for the Seattle model building are shown in Figures 1 and 2.

Table 9: 20-story building properties, Los Angeles, hazard level: 2/50 (20LA250).

Item	Value	Source
Basic wind speed at reference height in exposure C	95 mph	Fig. 26.5-1 ASCE 7-16
Type of exposure	B	user spec
h Building height	265 ft (80.67 m)	user spec
B Building width	120 ft (36.53 m)	user spec
L Building depth	100 ft (30.44 m)	user spec
n_1 Building natural frequency	0.25 Hz	analysis or rational approximation[1)]
ζ Damping ratio	0.02	rational assignment[2)]
C_{fx} Mean along-wind force coefficient	1.3	
β Mode exponent	1.0	user spec
Building density	0.04 slugs/ft^3	bldg function

1) for approximate natural frequencies see section 26.11.2 and C26.11 of the ASCE 7-16. For this example, since the building are designed and the properties of the building elements are known, the natural frequency is accurately calculated.

2) recommended values for damping ratio can be found in Table 11.2.1, Dynamics of Structures by Chopra, 4th ed. [3]

Procedure

Same as the previous example, in order to use the EVW app, input forces and building properties need to be known. Gust-effect factor is calculated as shown in Table 10.

Table 10: Gust-effect factor, 3LA250.

Item	Value	Source
FLEXIBLE BUILDING (all n_1)		
$\bar{z}$ Effective structure height	159.0 ft	0.6h (26.11.4 ASCE 7-16)
$I_{\bar{z}}$ Turbulence intensity at eff. height	0.231	eq. 26.11.7 ASCE 7-16
$L_{\bar{z}}$ Turbulence length scale at eff. height	540.5 ft	eq. 26.11.9 ASCE 7-16
V Basic wind speed	95 mph	Fig. 26.5-1 ASCE 7-16
β Damping ratio	0.02	rational assignment
$\bar{\alpha}$ Power law exponent of mean wind speed profile	0.25	Table 26.11-1 ASCE 7-16
$\bar{b}$ Gust factor 1/F at 10 m	0.45	Table 26.11-1 ASCE 7-16
$\bar{V}_{\bar{z}}$ Mean wind speed at effective height	92.9	eq. 26.11-16 ASCE 7-16
N_1 Reduced natural frequency	1.45	eq. 26.11-14 ASCE 7-16
R_n Resonance response factor for n	0.107	eq. 26.11-13 ASCE 7-16
η_h Vertical decay parameter	3.281	eq. 26.11-5 ASCE 7-16
η_B Cross-wind decay parameter	1.486	eq. 26.11-5 ASCE 7-16
η_L Along-wind decay parameter	4.145	eq. 26.11-5 ASCE 7-16
R_h Resonant factor for h	0.258	eq. 26.11-15a ASCE 7-16
R_B Resonant factor for B	0.458	eq. 26.11-15a ASCE 7-16
R_L Resonant factor for L	0.212	eq. 26.11-15a ASCE 7-16
R^2 Resonant response (squared)	0.399	eq. 26.11-12 ASCE 7-16
g_R Resonant peak factor	3.845	eq. 26.11-11 ASCE 7-16
G_f Gust-effect factor	0.97	eq. 26.11-10 ASCE 7-16

Therefore, Gust wind speed in mph is:

$$G_f \times C = 0.97 \times 95 = \boxed{92.2}$$

Thus, input forces and building properties used in the EVW app are shown in table below:

Table 11: Input forces and building properties (20LA250).

Input Forces		
Earthquake:	Input motion	Northridge
	Scale factor	0.01
Wind:	Exposure category	B
	Gust wind speed	92.2 mph
	Seed	100
Building Properties		
	Number floor	20
	Building weight	24419.5 k
	shape	Rectangular
	Height	3180 in.
	Width	1440 in.
	Length	1200 in.
	Drag coefficient	1.3
	Story stiffness	see Table 4
	Damping ratio	0.02
Disable PDelta effects		

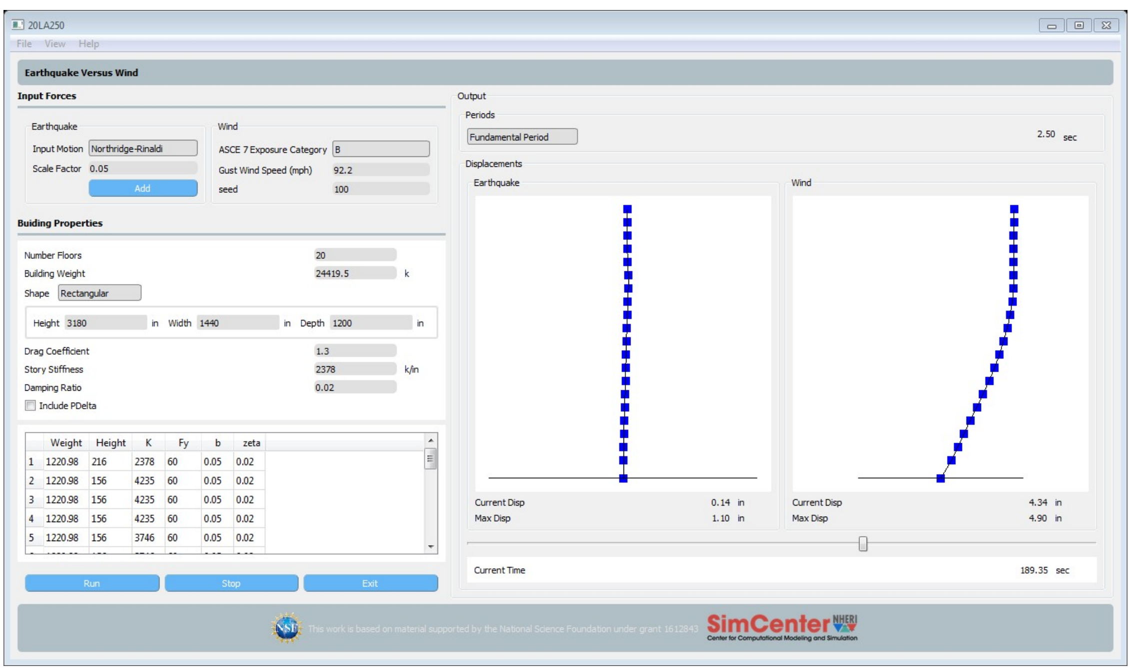


Figure 16: Program display after inputs entered for building 20LA250.

Following figures show some of the graphics available in the tool.

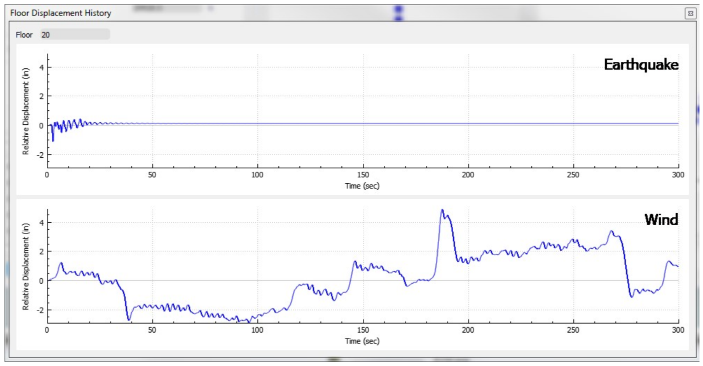


Figure 17: Floor displacement history, 20LA250, 20$^{\text{th}}$ floor.

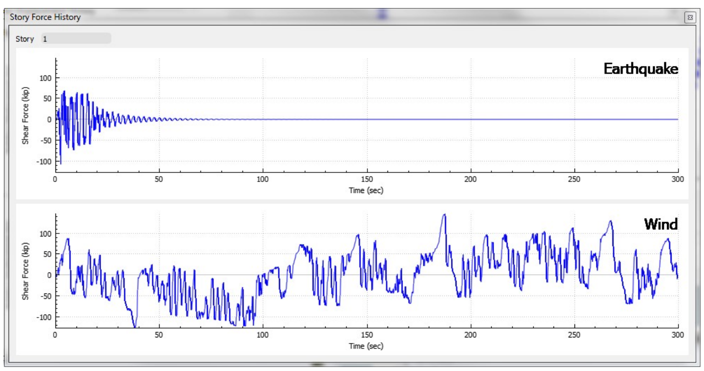


Figure 18: Story force history, 20LA250, first floor.

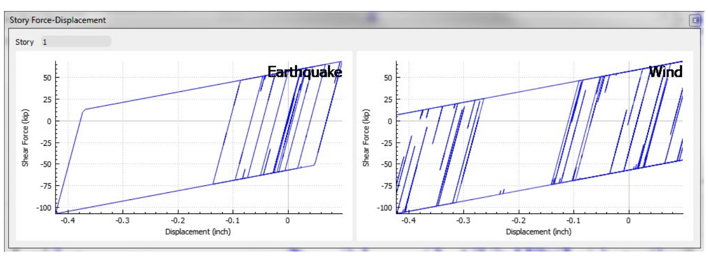


Figure 19: Story force displacement, 20LA250, first floor.

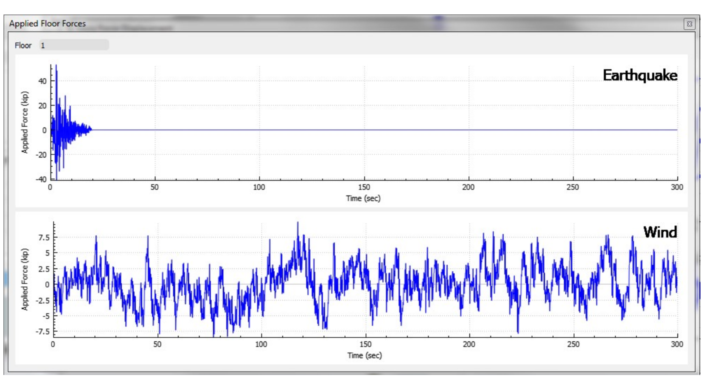


Figure 20: Applied floor forces, 20LA250, first floor.

Example 4: The SAC 20-story Seattle Building, Hazard Level 2/50 (20SE250)

Properties of the 20-story building located in Seattle for the hazard level of 2/50 are tabulated in Table 12. See Figures 1 and 2 for floor plans, elevations and plans of moment-resisting frames.

Table 12: 20-story building properties, Seattle, hazard level: 2/50 (20SE250).

Item	Value	Source
Basic wind speed at reference height in exposure C	98 mph	Fig. 26.5-1 ASCE 7-16
Type of exposure	B	user spec
h Building height	265 ft (80.67 m)	user spec
B Building width	120 ft (36.53 m)	user spec
L Building depth	100 ft (30.44 m)	user spec
n_1 Building natural frequency	0.26 Hz	analysis or rational approximation[1)]
ζ Damping ratio	0.02	rational assignment[2)]
C_{fx} Mean along-wind force coefficient	1.3	
β Mode exponent	1.0	user spec
Building density	0.04 slugs/ft^3	bldg function

[1)] for approximate natural frequencies see section 26.11.2 and C26.11 of the ASCE 7-16. For this example, since the building are designed and the properties of the building elements are known, the natural frequency is accurately calculated.

[2)] recommended values for damping ratio can be found in Table 11.2.1, Dynamics of Structures by Chopra, 4th ed. [3]

Procedure

Same as the previous example, in order to use the EVW app, input forces and building properties need to be known. Table 13 shows gust-effect factor calculations.

Table 13: Gust-effect factor, 3LA250.

Item	Value	Source
FLEXIBLE BUILDING (all n_1)		
$\bar{z}$ Effective structure height	159.0 ft	0.6h (26.11.4 ASCE 7-16)
$I_{\bar{z}}$ Turbulence intensity at eff. height	0.231	eq. 26.11.7 ASCE 7-16
$L_{\bar{z}}$ Turbulence length scale at eff. height	540.5 ft	eq. 26.11.9 ASCE 7-16
V Basic wind speed	98 mph	Fig. 26.5-1 ASCE 7-16
β Damping ratio	0.02	rational assignment
$\bar{\alpha}$ Power law exponent of mean wind speed profile	0.25	Table 26.11-1 ASCE 7-16
$\bar{b}$ Gust factor 1/F at 10 m	0.45	Table 26.11-1 ASCE 7-16
$\bar{V}_{\bar{z}}$ Mean wind speed at effective height	95.8	eq. 26.11-16 ASCE 7-16
N_1 Reduced natural frequency	1.47	eq. 26.11-14 ASCE 7-16
R_n Resonance response factor for n	0.107	eq. 26.11-13 ASCE 7-16
η_h Vertical decay parameter	3.307	eq. 26.11-5 ASCE 7-16
η_B Cross-wind decay parameter	1.498	eq. 26.11-5 ASCE 7-16
η_L Along-wind decay parameter	4.178	eq. 26.11-5 ASCE 7-16
R_h Resonant factor for h	0.257	eq. 26.11-15a ASCE 7-16
R_B Resonant factor for B	0.456	eq. 26.11-15a ASCE 7-16
R_L Resonant factor for L	0.211	eq. 26.11-15a ASCE 7-16
R^2 Resonant response (squared)	0.393	eq. 26.11-12 ASCE 7-16
g_R Resonant peak factor	3.855	eq. 26.11-11 ASCE 7-16
G_f Gust-effect factor	0.97	eq. 26.11-10 ASCE 7-16

Therefore, Gust wind speed in mph is:

$$G_f \times C = 0.97 \times 98 = \boxed{95.0}$$

Thus, input forces and building properties used in the EVW app are shown in table below:

Table 14: Input forces and building properties (20SE250).

Input Forces		
Earthquake:	Input motion	Northridge
	Scale factor	0.01
Wind:	Exposure category	B
	Gust wind speed	95.0 mph
	Seed	100
Building Properties		
	Number floor	20
	Building weight	24419.5 k
	shape	Rectangular
	Height	3180 in.
	Width	1440 in.
	Length	1200 in.
	Drag coefficient	1.3
	Story stiffness	see Table 4
	Damping ratio	0.02
Disable PDelta effects		

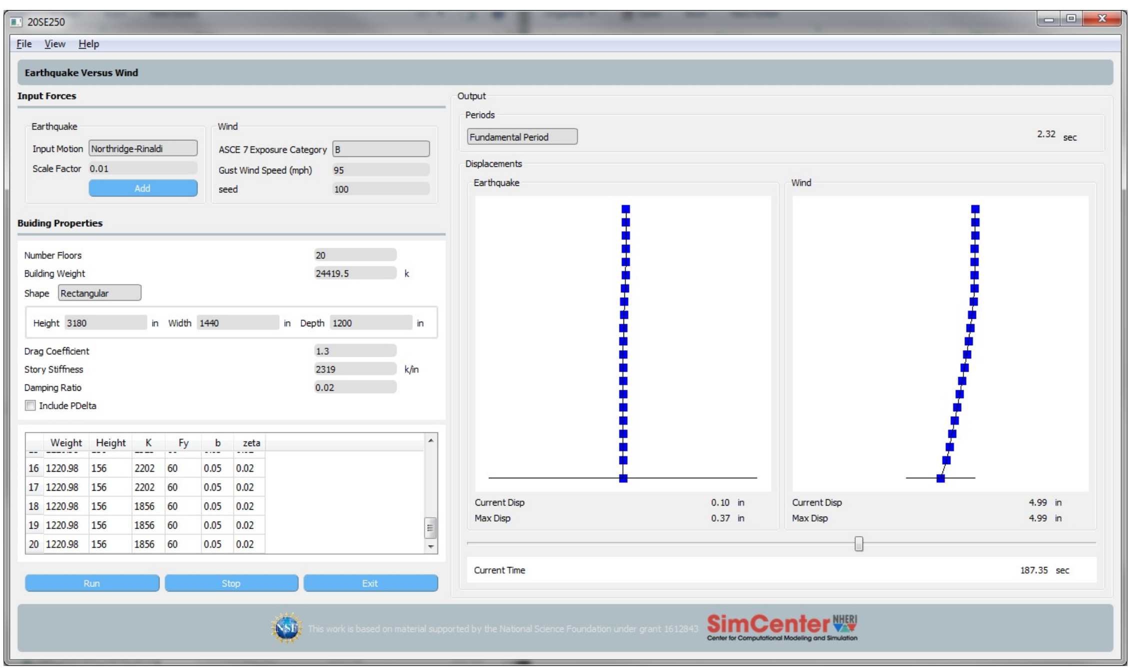


Figure 21: Program display after inputs entered for building 20SE250.

Following figures show some of the graphics available in the tool.

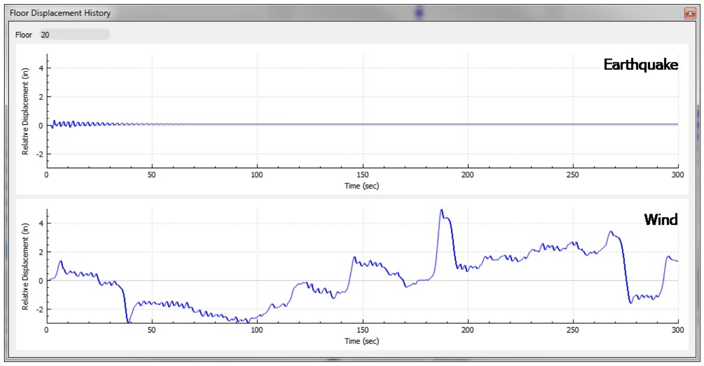


Figure 22: Floor displacement history, 20SE250, 20$^{\mathrm{th}}$ floor.

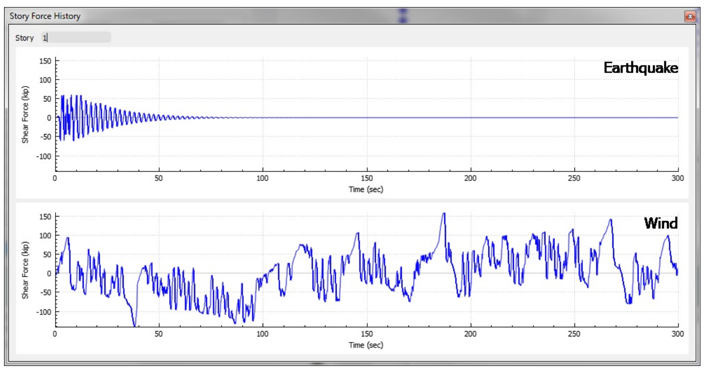


Figure 23: Story force history, 20SE250, first floor.

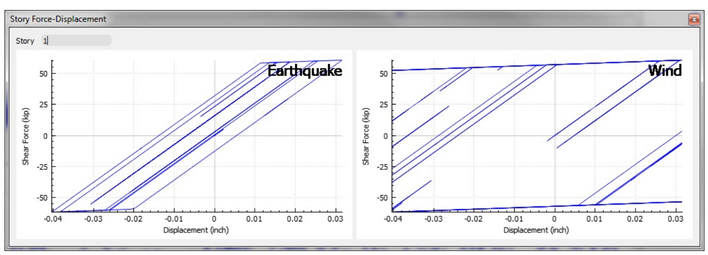


Figure 24: Story force displacement, 20SE250, first floor.

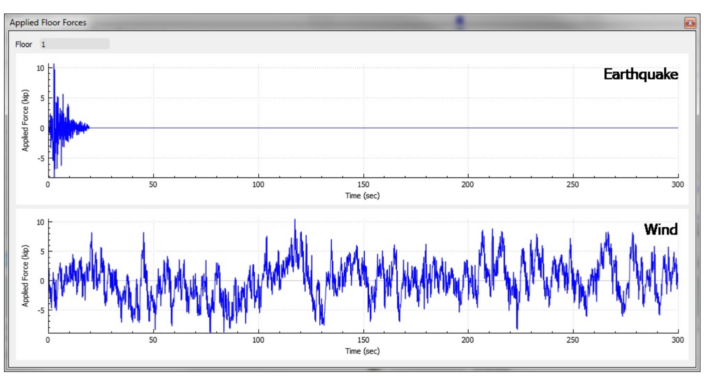
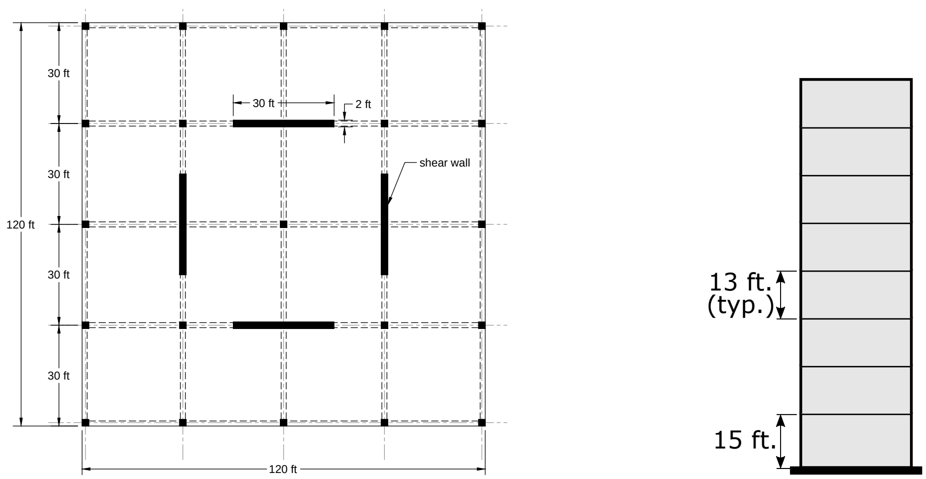


Figure 25: Applied floor forces, 20SE250, 20$^{\mathrm{th}}$ floor.

Example 5: Walled Building

In this example, an 8-story walled building is taken into consideration where only the walls contribute to the lateral resistance. Therefore, for stiffness consideration, only walls will be considered. Floor plan and elevation of the building and locations of walls are shown in Figure 26. The building is located in Los Angeles. This example is adopted from the final report for the Applied Technology Councils project (ATC123 project); (Report to project technical committee and project review) [5].

To find the stiffness of this building, as explained earlier, point loads were applied at top of the first story and then the stiffness was calculated based on the displacements caused by the point loads.



(a) Plan **(b)** Elevation

Figure 26: Floor plan and elevation of the 8-story walled building.

Properties of the 8-story walled building is shown in table below.

Table 15: 8-story walled building properties.

Item	Value	Source
Basic wind speed at reference height in exposure C	95 mph	Fig. 26.5-1 ASCE 7-16
Type of exposure	B	user spec
h Building height	106 ft (32.27 m)	user spec
B Building width	120 ft (36.53 m)	user spec
L Building depth	120 ft (36.53 m)	user spec
n_1 Building natural frequency	0.88 Hz	analysis or rational approximation$^{1)}$
ζ Damping ratio	0.02	rational assignment$^{2)}$
C_{fx} Mean along-wind force coefficient	1.3	
β Mode exponent	1.0	user spec
Building density	0.433 slugs/ft^3	bldg function

$^{1)}$ for approximate natural frequencies see section 26.11.2 and C26.11 of the ASCE 7-16. For this example, since the building are designed and the properties of the building elements are known, the natural frequency is accurately calculated.

$^{2)}$ recommended values for damping ratio can be found in Table 11.2.1, Dynamics of Structures by Chopra, 4th ed. [3]

Procedure

Same as the previous example, in order to use the EVW app, input forces and building properties need to be known. Table 16 shows gust-effect factor calculations.

Table 16: Gust-effect factor, 3LA250.

Item	Value	Source
FLEXIBLE BUILDING (all n_1)		
$\bar{z}$ Effective structure height	63.6 ft	0.6h (26.11.4 ASCE 7-16)
$I_{\bar{z}}$ Turbulence intensity at eff. height	0.267	eq. 26.11.7 ASCE 7-16
$L_{\bar{z}}$ Turbulence length scale at eff. height	398.2 ft	eq. 26.11.9 ASCE 7-16
V Basic wind speed	95 mph	Fig. 26.5-1 ASCE 7-16
β Damping ratio	0.02	rational assignment
$\bar{\alpha}$ Power law exponent of mean wind speed profile	0.25	Table 26.11-1 ASCE 7-16
$\bar{b}$ Gust factor 1/F at 10 m	0.45	Table 26.11-1 ASCE 7-16
$\bar{V}_{\bar{z}}$ Mean wind speed at effective height	73.9	eq. 26.11-16 ASCE 7-16
N_1 Reduced natural frequency	4.74	eq. 26.11-14 ASCE 7-16
R_n Resonance response factor for n	0.052	eq. 26.11-13 ASCE 7-16
η_h Vertical decay parameter	5.808	eq. 26.11-5 ASCE 7-16
η_B Cross-wind decay parameter	6.575	eq. 26.11-5 ASCE 7-16
η_L Along-wind decay parameter	22.013	eq. 26.11-5 ASCE 7-16
R_h Resonant factor for h	0.157	eq. 26.11-15a ASCE 7-16
R_B Resonant factor for B	0.141	eq. 26.11-15a ASCE 7-16
R_L Resonant factor for L	0.044	eq. 26.11-15a ASCE 7-16
R^2 Resonant response (squared)	0.032	eq. 26.11-12 ASCE 7-16
g_R Resonant peak factor	4.159	eq. 26.11-11 ASCE 7-16
G_f Gust-effect factor	0.85	eq. 26.11-10 ASCE 7-16

Therefore, Gust wind speed in mph is:

$$G_f \times C = 0.85 \times 95 = \boxed{80.75}$$

Thus, input forces and building properties used in the EVW app are shown in table below:

Table 17: Input forces and building properties (20SE250).

Input Forces		
Earthquake:	Input motion	Northridge
	Scale factor	0.01
Wind:	Exposure category	B
	Gust wind speed	95.0 mph
	Seed	100
Building Properties		
	Number floor	8
	Building weight	21276.0 k
	shape	Rectangular
	Height	1272 in.
	Width	1440 in.
	Drag coefficient	1.3
	Story stiffness	6200.0 k/in.
	Damping ratio	0.02
Enable PDelta effects		

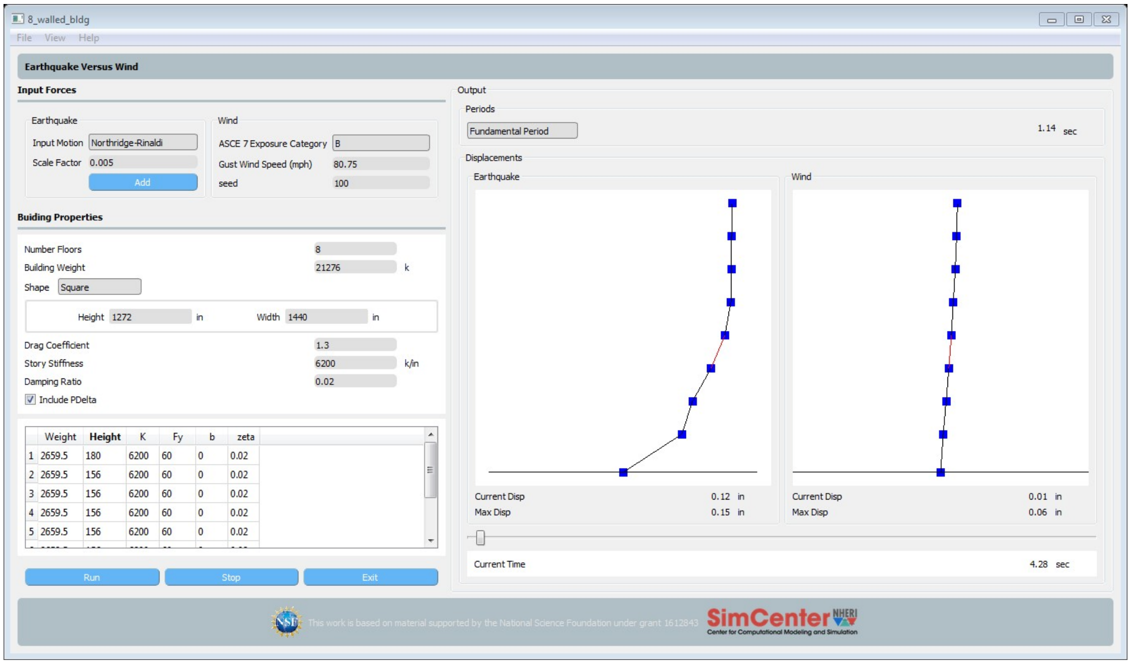


Figure 27: Program display after inputs entered for 8-story walled building.

Following figures show some of the graphics available in the tool.

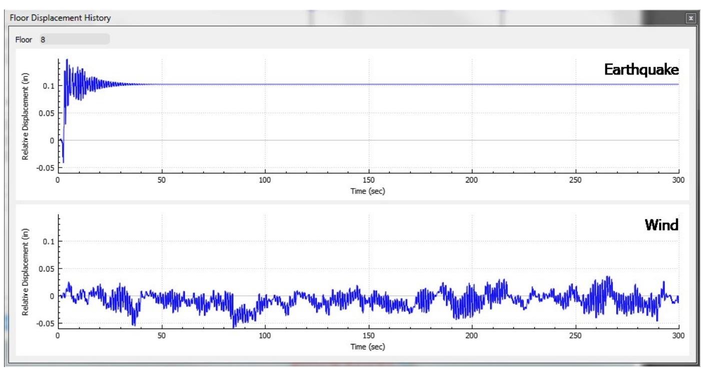


Figure 28: Floor displacement history, 8-story walled biuilding, 8^{th} floor.

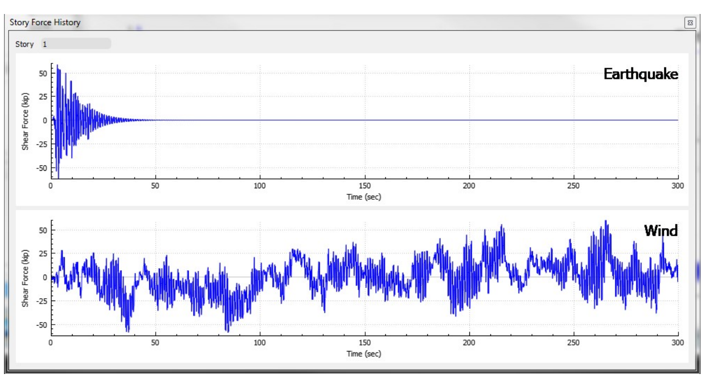


Figure 29: Story force history, 8-story walled biuilding, first floor.

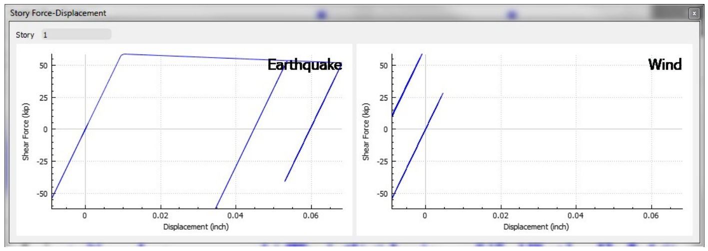


Figure 30: Story force displacement, 8-story walled biuilding, first floor.

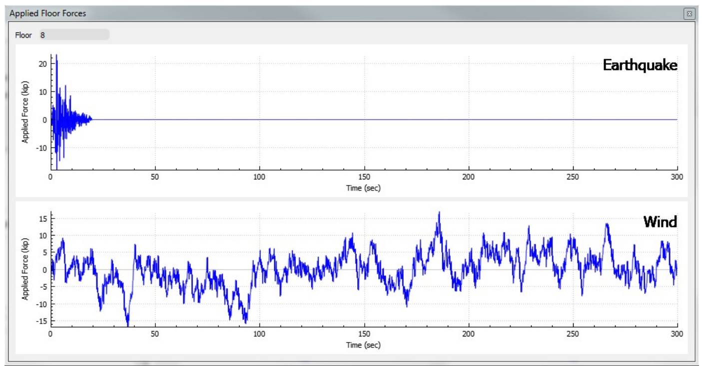


Figure 31: Applied floor forces, 8-story walled biuilding, 8$^{\text{th}}$ floor.

References

[1] *Steel Construction Manual*. American Institute of Steel Construction, Chicago, Illinois, fifteenth edition, 2017. ISBN 9781564240071.

[2] ASCE7-16. *Minimum Design Loads for Buildings and Other Structures*. ASCE/SEI Standard 7-16, 2016.

[3] Anil K Chopra. *Dynamics of structures : theory and applications to earthquake engineering*. Prentice-Hall international series in civil engineering and engineering mechanics. Prentice Hall, Upper Saddle River, N.J., 4th ed. edition, 2012. ISBN 9780132858038.

[4] FEMA335C. *State of the Art Report on Systems Performance of Steel Moment Frames Subject to Earthquake Ground Shaking*. 2000. URL https://www.nehrp.gov/pdf/fema355c.pdf.

[5] FEMA P-2012. *Assessing Seismic Performance of Buildings with Confi guration Irregularities: Calibrating Current Standards and Practices*. 2018.

[6] Edward L Wilson and A Habibullah. Structural Analysis Program SAP2000. *Computers and Structures Inc., California*, 2016.