

# SEISMIC ANALYSIS

In SAFI, **three approaches** are possible to obtain the maximum displacements and forces of a structure subjected to an earthquake. The first approach is a **static equivalent** seismic load which is obtained from the equivalent lateral force method. The second and the third approach are a **response spectrum** analysis and a **time-history** analysis.

These analysis can be run based on the *National Building Code of Canada (NBCC)*, or the *Minimum Design Loads for Buildings and Other Structures (ASCE)*.

The parameters defined here are defined only once for the whole structure, they are common for all the seismic loads.

The screenshot shows the 'Seismic' tab in a software interface. It includes the following fields and options:

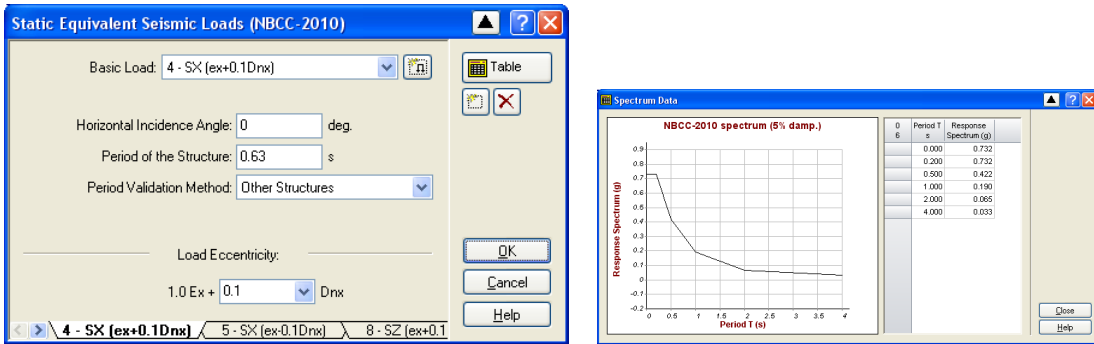
- Code: Canada - NBCC-2010
- Structure Category: Structure with Storeys (Building)
- Structure Location: Québec (Québec) - Quebec - Canada
- Site Parameters: Site Class: A - Hard Rock
- Seismic coefficients:  $S_a(0.2) = 0.55$  g,  $S_a(1.0) = 0.15$  g,  $S_a(0.5) = 0.32$  g,  $S_a(2.0) = 0.052$  g,  $F_a = 0.72$ ,  $F_v = 0.5$
- Model Data: Seismic Force Resisting System (SFRS) with Importance Factor (I<sub>e</sub>) = 1.5, Type of SFRS = Steel structure (Moderately ductile concentrically braced frame (Tension only)), Lateral Resisting System = Braced frame, Ductility Factor (R<sub>d</sub>) = 3, Overstrength Factor (R<sub>o</sub>) = 1.3, Restriction = Height limited to 20000 mm, Seismic Force Distribution with Y Coordinate of the Ground = 0 mm, and Seismic Weight (W) = 1 - Poids sismique (W)

The screenshot shows the 'Regional Data' dialog box with the following information:

- Country: Canada, Region: Quebec, City: Montréal (Montréal)
- Elevation: 20000 mm
- Snow Data: Snow Pressure (S<sub>s</sub>) - (1.50): 2.6 kN/m<sup>2</sup>, Rain Pressure (S<sub>r</sub>) - (1.50): 0.4 kN/m<sup>2</sup>
- Wind Data: Wind Pressure (1:10): 0.33 kN/m<sup>2</sup>, Wind Pressure (1:50): 0.42 kN/m<sup>2</sup>
- Seismic Data:  $S_a(0.2) = 64$  % g,  $S_a(0.5) = 31$  % g,  $S_a(1.0) = 14$  % g,  $S_a(2.0) = 4.8$  % g

## STATIC EQUIVALENT SEISMIC ANALYSIS

The seismic load is defined for each seismic direction.

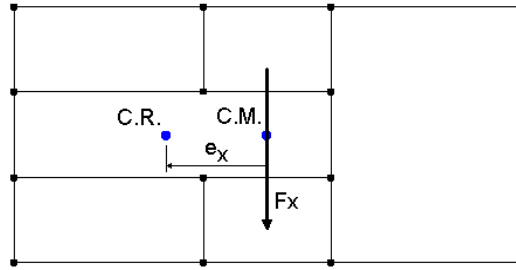


The **Seismic Floor Data** table contains the data for each floors which are the mass (Wi) of the floor, the mean elevation (center of gravity) of the floor with respect to the Y coordinate of the ground and the X and Z coordinates of the center of mass and the center of stiffness.

0	Floor	Y Min mm	Y Max mm	Wi kN	Hi mm	Cmass,x mm	Cmass,z mm	Cstiff,x mm	Cstiff,z mm	Corr x	Corr z
3	1	0.0000	4001.0000	2237.7542	4000.0000	12014.1113	6000.0000	6844.1929	6033.3267	0.9998	0.9998
	2	4001.0000	8001.0000	2282.2073	7999.9995	12175.8115	6000.0005	5838.6099	6007.6802	1.0000	1.0000
	3	8001.0000	12001.0000	1772.0920	12000.0000	9011.2061	6000.0000	5270.6733	6006.2612	1.0000	1.0000

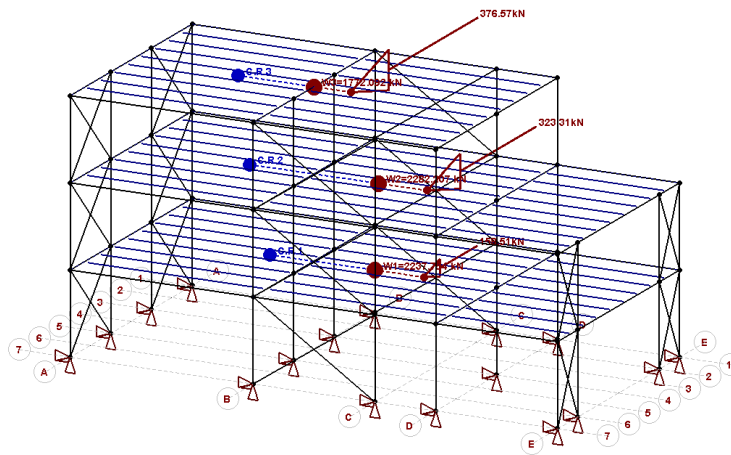
The **Seismic Floor Loads** table contains the results for the various seismic loads at each floor which are: the total force **Fx** of the seismic load applied to each floor, the torsional moment around the vertical Y axis, the dimension of the structure (Dnx) perpendicular to the seismic direction, the eccentricity (Ex) between the center of mass and the center of rigidity, the ratio Bx representing the sensibility to torsion and the overturning moment Mx.

0	Load ID	Load Name	Floor	Y Min mm	Y Max mm	FX Floor kN	VX Floor kN	Torsion kN-m	Dnx mm	Ex mm	Bx	Jx	Mx kN-m
24	4	SX (ex+0.1Dnx)	1	0.0000	4001.0000	175.0403	772.8817	210.0484	12000.0000	-33.3257	1.0597	0.9808	4663.3979
	4	SX (ex+0.1Dnx)	2	4001.0000	8001.0000	357.0349	415.8466	428.4420	12000.0000	-7.6792	1.0708	1.0000	1663.3867
	4	SX (ex+0.1Dnx)	3	8001.0000	12001.0000	415.8466	0.0000	499.0160	12000.0000	-6.2612	1.0795	1.0000	0.0000
	5	SX (ex-0.1Dnx)	1	0.0000	4001.0000	175.0403	772.8817	-210.0484	12000.0000	-33.3257	1.0597	0.9808	4663.3979
	5	SX (ex-0.1Dnx)	2	4001.0000	8001.0000	357.0349	415.8466	-428.4420	12000.0000	-7.6792	1.0708	1.0000	1663.3867
	5	SX (ex-0.1Dnx)	3	8001.0000	12001.0000	415.8466	0.0000	-499.0160	12000.0000	-6.2612	1.0795	1.0000	0.0000
	6	SX (ex+0.1Dnx) spec	1	0.0000	4001.0000	297.6780	718.9474	210.0484	12000.0000	-33.3257	1.0597	0.0000	4540.9951
	6	SX (ex+0.1Dnx) spec	2	4001.0000	8001.0000	311.3058	469.6031	428.4420	12000.0000	-7.6792	1.0708	0.0000	1878.4120
	6	SX (ex+0.1Dnx) spec	3	8001.0000	12001.0000	338.9382	0.0000	499.0160	12000.0000	-6.2612	1.0795	0.0000	0.0000

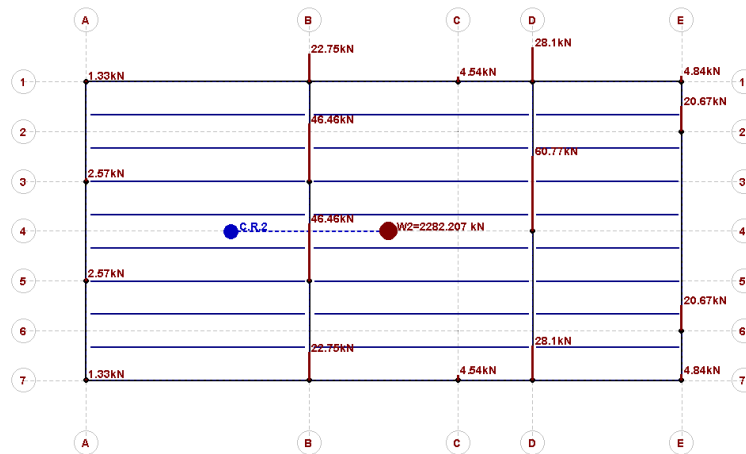


In the NBCC and ASCE 7 codes, when the stability coefficient is smaller than 0.1, the P-Delta effects may be neglected. When the P-Delta effects cannot be neglected, these codes recommend to design the structure so that each storey can resist a seismic shear force amplified by the value  $(1 + \theta_x)$ . In the program, this amplification is not applied automatically to the analysis results.

In the figure below, the center of mass and the center of rigidity are displayed as well as the floor forces



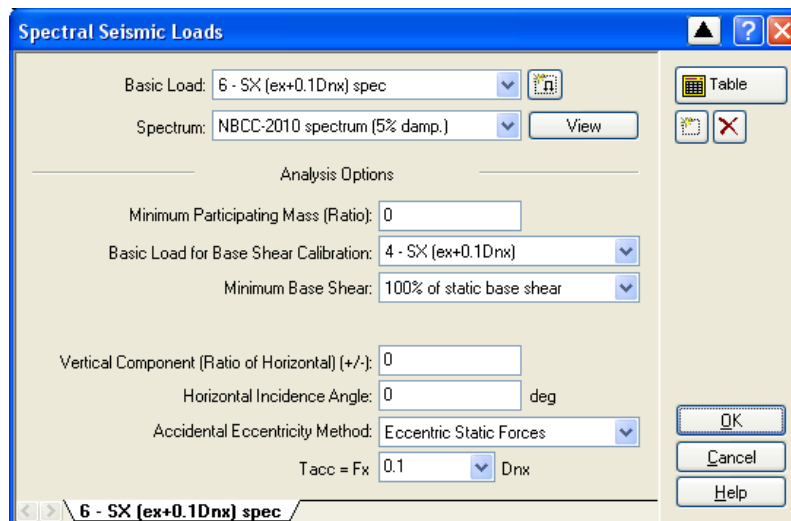
The following figure shows the joint static seismic forces at floor 2 including the the distribution of the seismic forces with the accidental torsion (e.g. with the effect of accidental eccentricity).



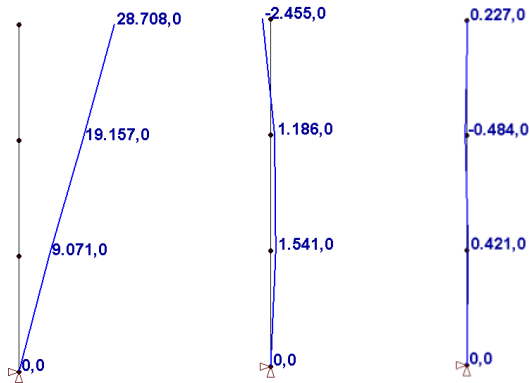
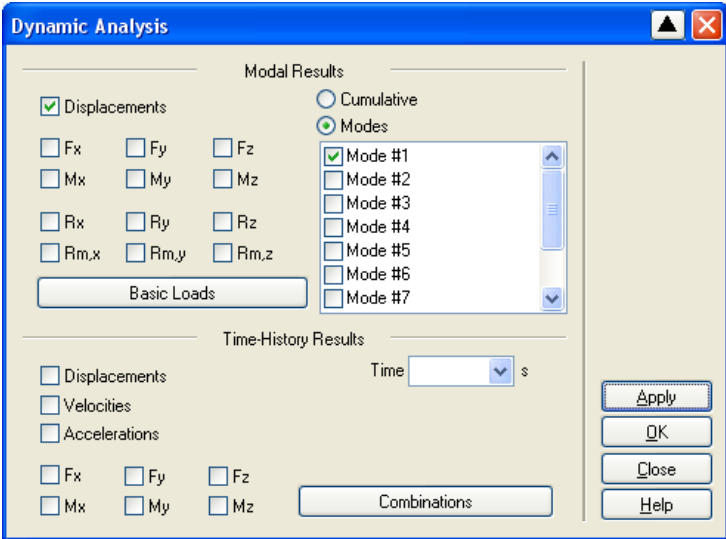
## SPECTRAL AND TIME-HISTORY SEISMIC ANALYSIS

The seismic response spectrum analysis allows to estimate the maximum displacements and corresponding forces. The seismic analysis with response spectrum allows to obtain the maximum joint displacements, forces in members and support reactions for an earthquake. The response spectrum of the earthquake acceleration is defined as being the maximum of the spectral response according to the period (T). The response spectrum is user defined. The modal analysis results are combined by the SRSS or CQC method to obtain a maximum. This maximum can be combined with the static results for the purpose of structural design computations and design work. To take the earthquake reversibility into account, positive and negative combinations of earthquake loads must be considered.

The seismic load is defined for each seismic direction. The base shear calibration is performed on the corresponding static seismic load.



The influence of each mode on the final analysis results may be displayed graphically and in tables.



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