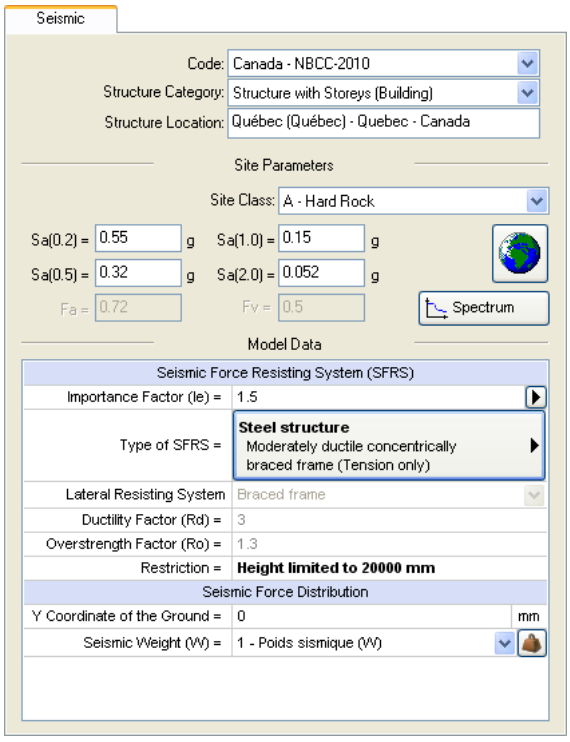
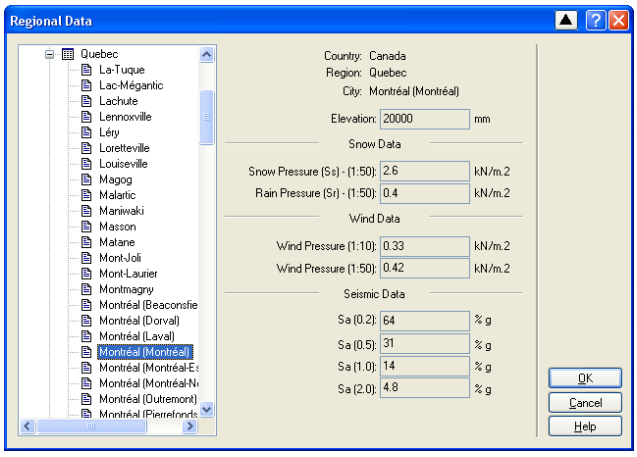
# SEISMIC ANALYSIS

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)*.

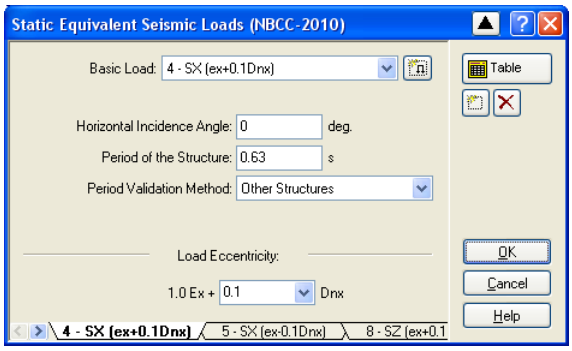
The parameters defined here are defined only once for the whole structure, they are common for all the seismic loads.

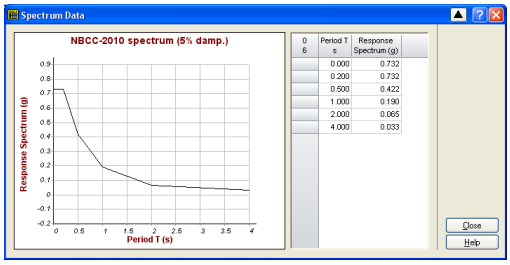


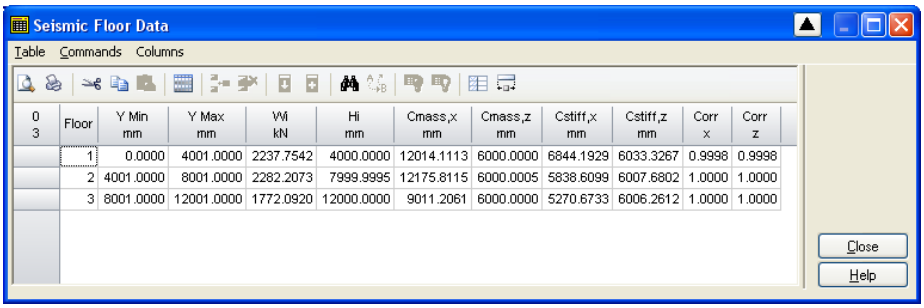
## STATIC EQUIVALENT SEISMIC ANALYSIS

The seismic load is defined for each seismic direction.



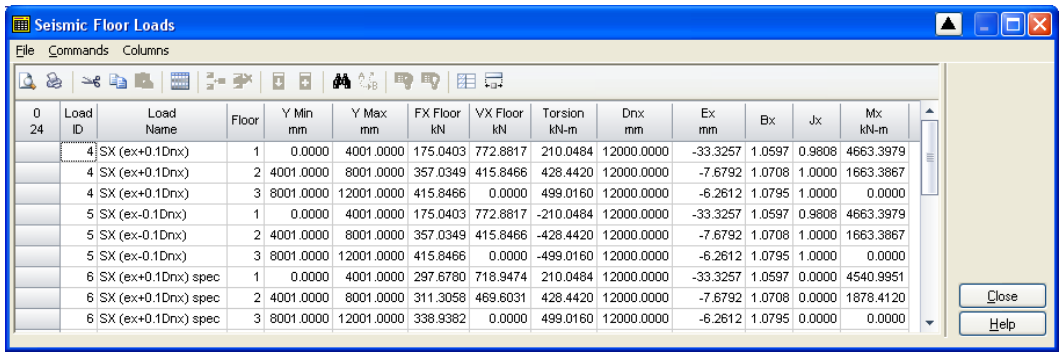




The **Seismic Floor Data** table contains the data for each floors which are the mass (Wi) of the floor, the mean elevation (center of gravity) of the floor with respect to the Y coordinate of the ground and the X and Z coordinates of the center of mass and the center of stiffness.

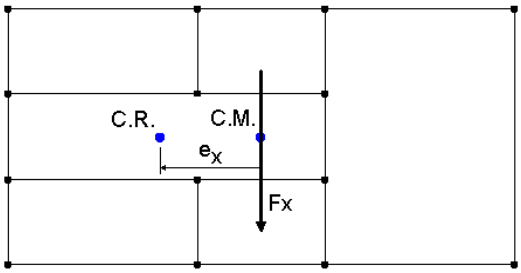



| 0 3 | Floor | Y Min mm | Y Max mm | Wi kN | Hi mm | Cmass,x mm | Cmass,z mm | Cstiff,x mm | Cstiff,z mm | Corr x | Corr z |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 0.0000 | 4001.0000 | 2237.7542 | 4000.0000 | 12014.1113 | 6000.0000 | 6844.1929 | 6033.3267 | 0.9998 | 0.9998 |
| | 2 | 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.

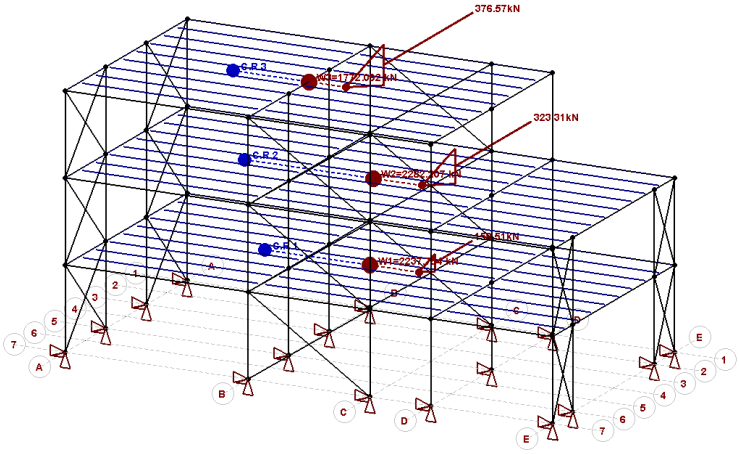



| 0 24 | Load ID | Load Name | Floor | Y Min mm | Y Max mm | FX Floor kN | VX Floor kN | Torsion kN-m | Dnx mm | Ex mm | Bx | Jx | Mx kN-m |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | SX (ex+0.1Dnx) | 1 | 0.0000 | 4001.0000 | 175.0403 | 772.8817 | 210.0484 | 12000.0000 | -33.3257 | 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 |

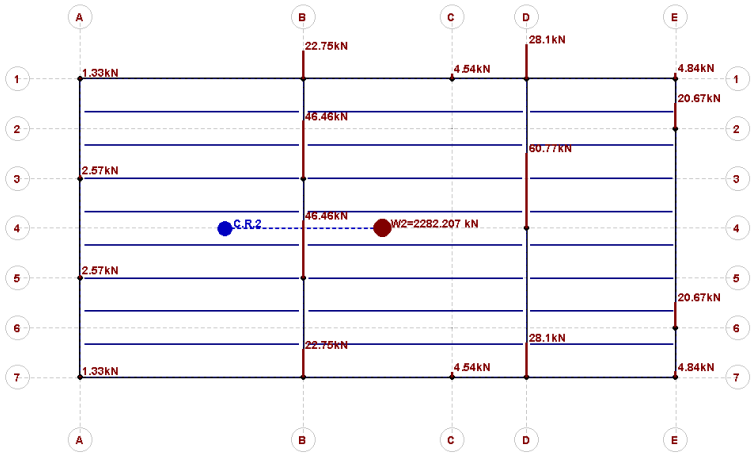



In the NBCC and ASCE 7 codes, when the stability coefficient is smaller than 0.1, the P-Delta effects may be neglected. When the P-Delta effects cannot be neglected, these codes recommend to design the structure so that each storey can resist a seismic shear force amplified by the value $(1+\theta_x)$.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



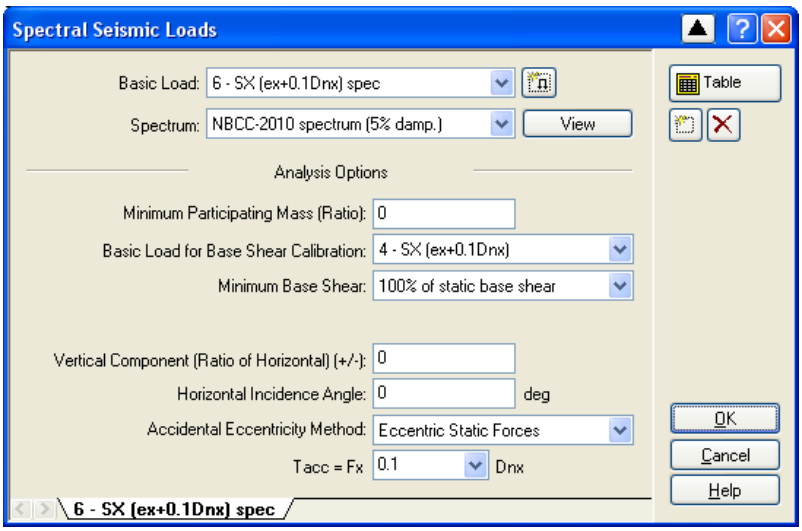
The following figure shows the joint static seismic forces at floor 2 including the the distribution of the seismic forces with the accidental torsion (e.g. with the effect of accidental eccentricity).



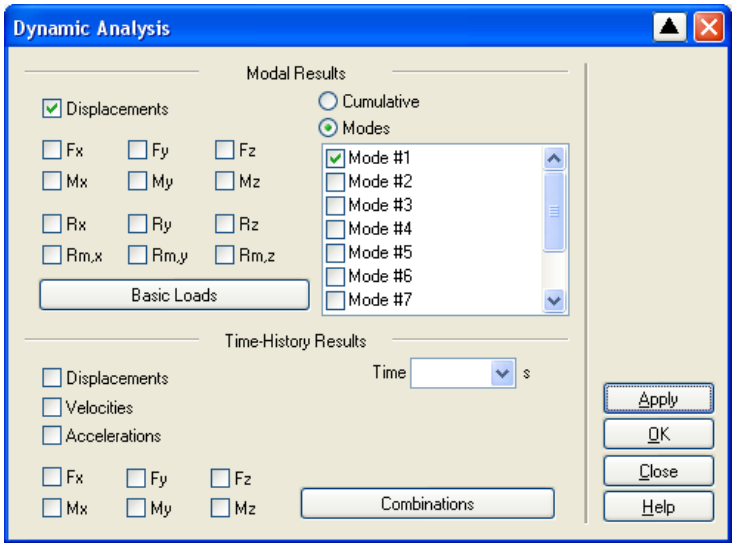

## SPECTRAL AND TIME-HISTORY SEISMIC ANALYSIS

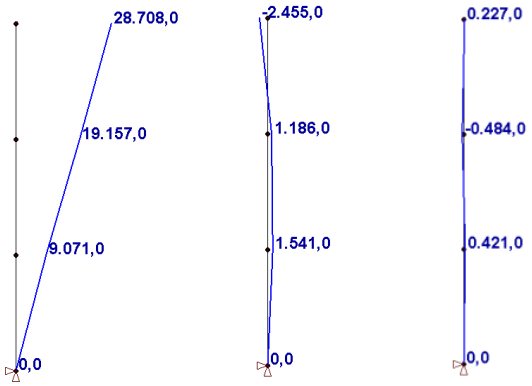
The seismic response spectrum analysis allows to estimate the maximum displacements and corresponding forces. The seismic analysis with response spectrum allows to obtain the maximum joint displacements, forces in members and support reactions for an earthquake. The response spectrum of the earthquake 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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