# SEISMIC ANALYSIS AND DESIGN AS PER EC 8 IN ETABS 2016 AND SAP2000 V19

## I. Overview

Seismic analysis and design as per Eurocode 8 can be done quite easily with the built-in features of ETABS 2016 and SAP2000 v19.

ETABS 2016/SAP2000 v19 are capable to perform the following methods of seismic analysis and design:

- **Equivalent Lateral Force Method (Static, Linear)**
- **Response Spectrum Analysis (Dynamic, Linear)**
- Time-History Analysis (Dynamic, Linear or Nonlinear)
- PBD -Performance Based Design (Static or Dynamic, Nonlinear)

This technical note will focus on seismic analysis and design using Equivalent Lateral Force Method (ELF) and Response Spectrum Analysis (RSA).

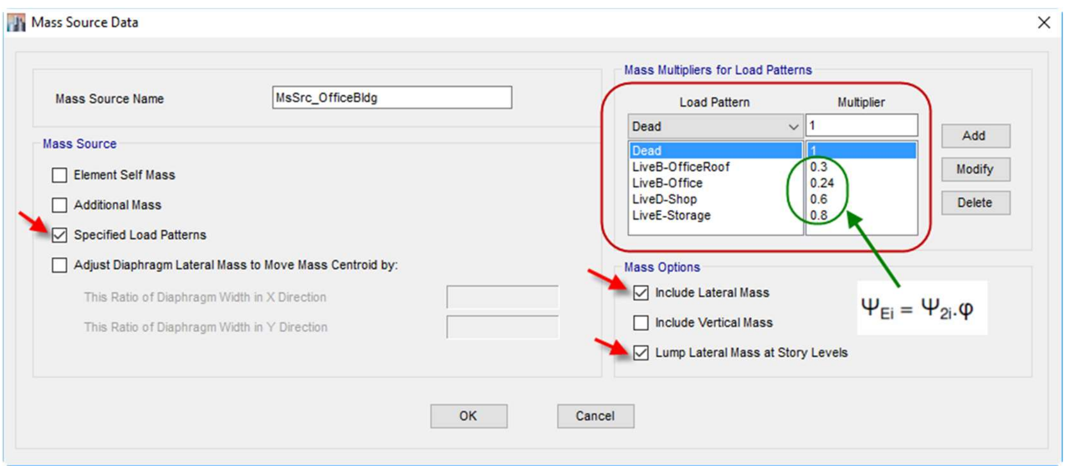
## II. Defining Seismic Mass Source

For both ELF and RSA methods, seismic mass source will first need to be defined. The weight of the structure used in the calculation of automatic seismic loads is based on the specified mass of the structure, and is termed ***mass source*** in ETABS 2016 and SAP2000 v19.

In EC8, the storey weight, $W_i$ at storey *i*, taken when calculating the seismic actions should comprise the full permanent load plus the variable load multiplied by a factor $\Psi_{Ei}$. $\Psi_{Ei}$ is equal to $\Psi_{2i}$ multiplied by a reduction factor φ.

Values of $\Psi_{2i}$ and φ are National Determined Parameters and reference should be made to specific National Annexes. Note that these factors differ with occupancy category (residential, offices, shops, etc.). Thus, mass source definition could be different from projects to projects.

To define the seismic mass source, click on **Define>Mass Source...** then define mass source as below:



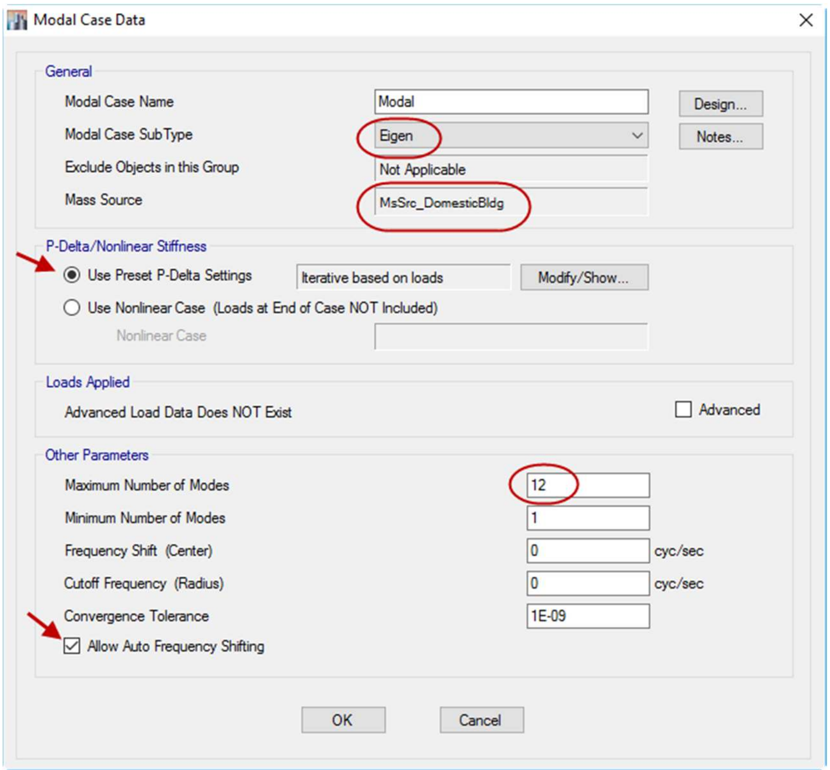
## III. Defining Modal Analysis

Modal Analysis results give modal frequencies/period and mode shapes that are primarily used in Response Spectrum Analysis in ETABS 2016 and SAP2000 v19.

The fundamental modal periods on the two main orthogonal directions reported from the modal analysis can be used in calculating the base shear for Equivalent Lateral Force Method.

Modal analysis type can be either Eigen vector or Ritz vector.

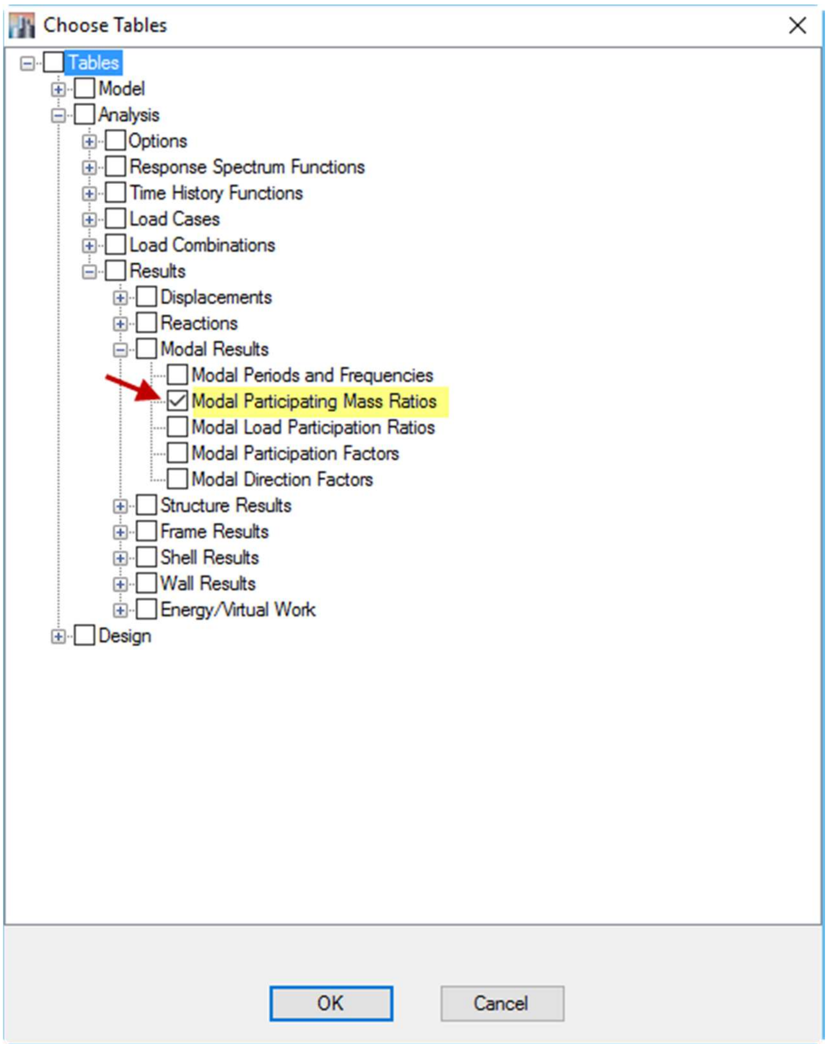
To define a Modal Analysis load case, click on **Define>Modal Cases…**




The maximum number of modes specified should be sufficient to meet the 90% mass participation requirement by the code. This requirement is to ensure that the response of all modes of vibration contributing significantly to the global response has been taken into account.

After running modal analysis, Modal Mass Participation can be checked in ETABS 2016 and SAP2000 v19:

Click on **Display>Show Tables…** and tick Modal Participating Mass Ratios under Results> Modal Results.




Modal Participating Mass Ratios

1 of 12 | Reload | Apply | Modal Participating Mass Ratios

| Case | Mode | Period sec | UX | UY | UZ | Sum UX | Sum UY | Sum UZ | |
|---|---|---|---|---|---|---|---|---|---|
| Modal | 1 | 0.37 | 0.1844 | 0.1133 | 0 | 0.1844 | 0.1133 | 0 | 0. |
| Modal | 2 | 0.258 | 0.2876 | 0.4229 | 0 | 0.472 | 0.5362 | 0 | 0. |
| Modal | 3 | 0.194 | 0.2562 | 0.1802 | 0 | 0.7282 | 0.7164 | 0 | 0. |
| Modal | 4 | 0.093 | 0.0508 | 0.0295 | 0 | 0.779 | 0.7459 | 0 | 0. |
| Modal | 5 | 0.06 | 0.0865 | 0.1171 | 0 | 0.8655 | 0.863 | 0 | 0. |
| Modal | 6 | 0.046 | 0.0631 | 0.0529 | 0 | 0.9286 | 0.9159 | 0 | 0. |
| Modal | 7 | 0.044 | 0.0071 | 0.0113 | 0 | 0.9357 | 0.9272 | 0 | 0. |
| Modal | 8 | 0.029 | 0.006 | 0.0045 | 0 | 0.9416 | 0.9318 | 0 | 0. |
| Modal | 9 | 0.028 | 0.0245 | 0.0308 | 0 | 0.9662 | 0.9625 | 0 | 0. |
| Modal | 10 | 0.022 | 0.002 | 0.0009 | 0 | 0.9682 | 0.9634 | 0 | 0. |
| Modal | 11 | 0.021 | 0.0121 | 0.0145 | 0 | 0.9803 | 0.9779 | 0 | 0. |
| Modal | 12 | 0.019 | 3.762E-05 | 0.0012 | 0 | 0.9803 | 0.9791 | 0 | 0. |

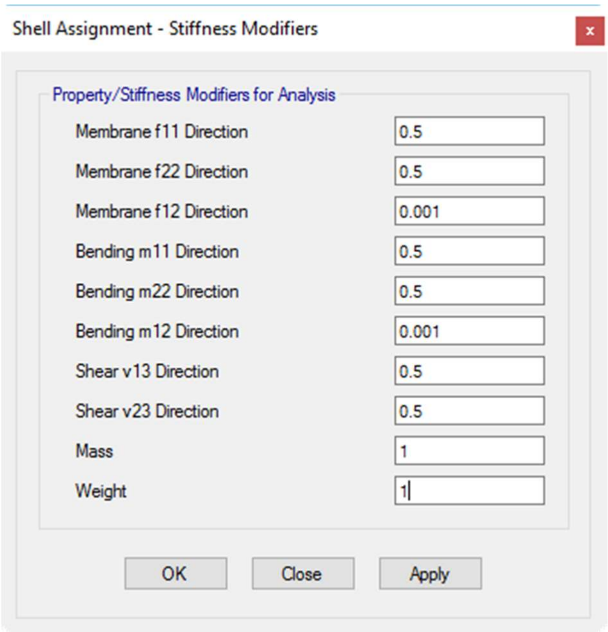
More than 90% mass participation means number of modes is sufficient.

## IV. Accounting for Effect of Cracking

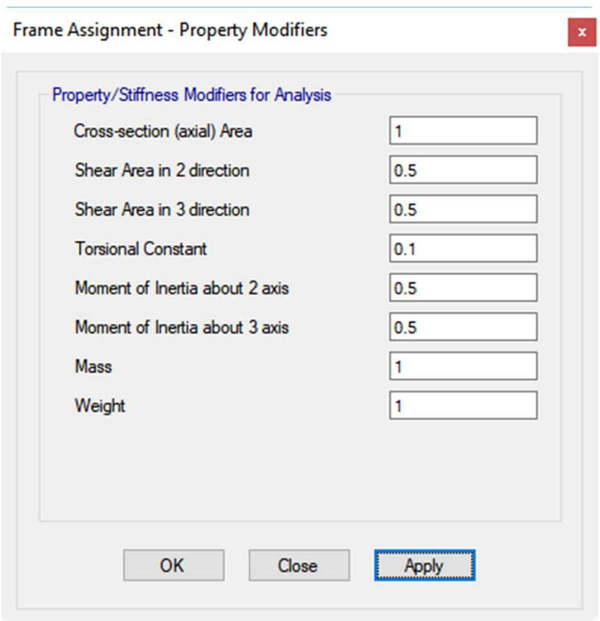
EC8 also requires that the stiffness of all load bearing elements must account for the effect of cracking. EC8 also states that unless a more accurate analysis of the cracked elements is performed, the elastic flexural and shear stiffness properties of concrete elements may be taken to be equal to one-half of the corresponding stiffness of the uncracked sections.

To satisfy the above requirements, stiffness properties of slabs with shell properties, beams, columns, and walls has to be reduced to 50%.

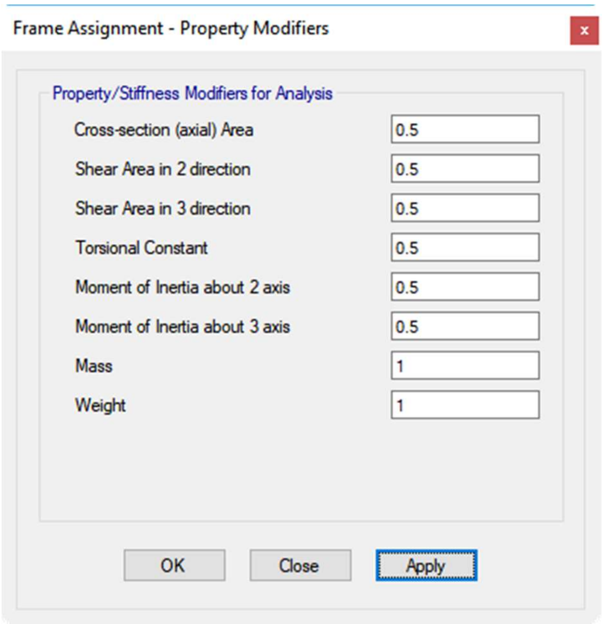
To reduce the stiffness properties of slabs with shell properties, select the slabs, and click on **Assign>Shell>Stiffness Modifiers…**



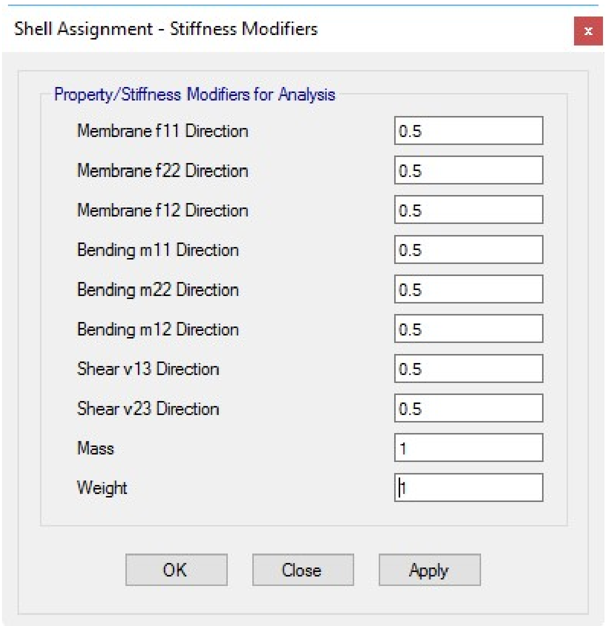

To reduce the stiffness properties of beams, select the beams and click on **Assign>Frame>Property Modifiers…**



To reduce the stiffness properties of columns, select the columns and click on **Assign>Frame>Property Modifiers…**




To reduce the properties of walls, select the walls, and click on **Assign>Shell>Stiffness Modifiers…**



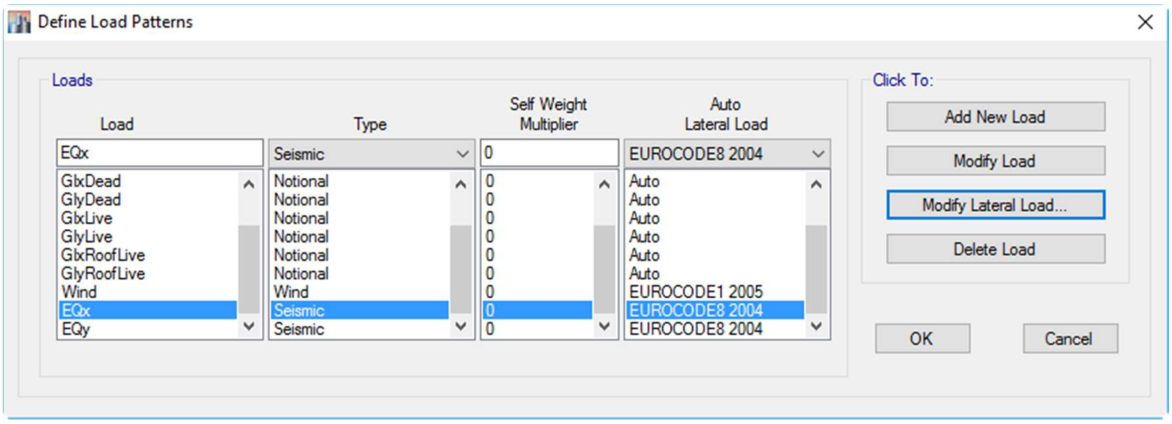

## V. Defining Auto Seismic Loads for Equivalent Lateral Force Method

In Equivalent Lateral Force Method, the Base Shear is determined using code based procedures. The calculated Base Shear is then distributed through all the stories in relation to the storey weight and height from the base.

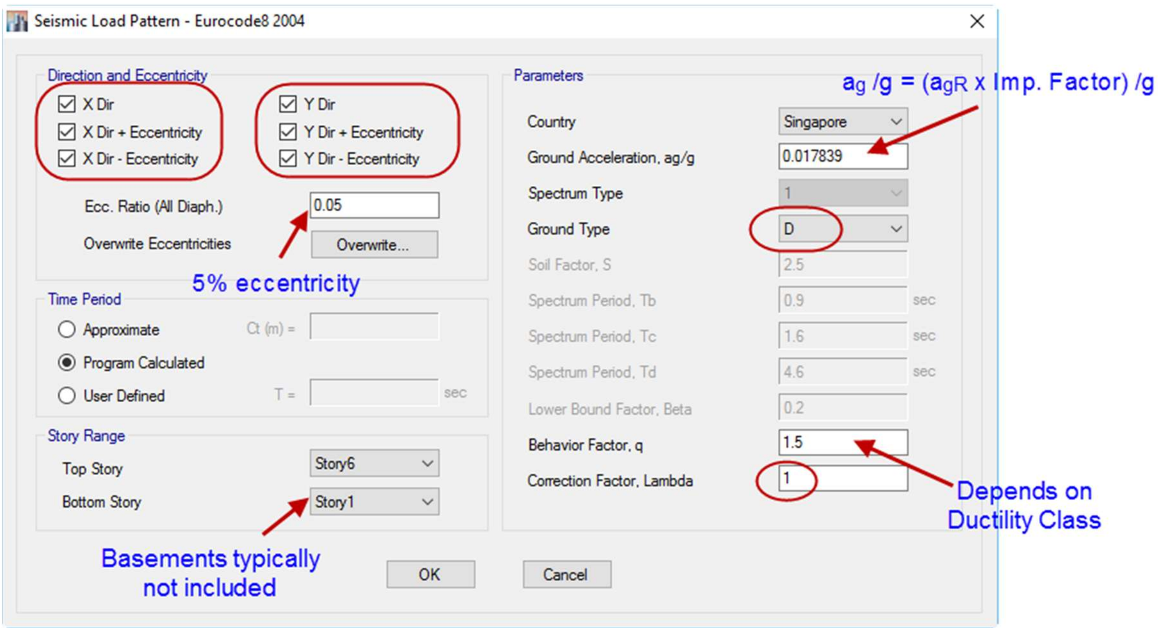
Use of Equivalent Lateral Force Method should be limited for simple regular buildings, without elevation regularity, and the fundamental periods in the two main directions are less than 2 seconds.

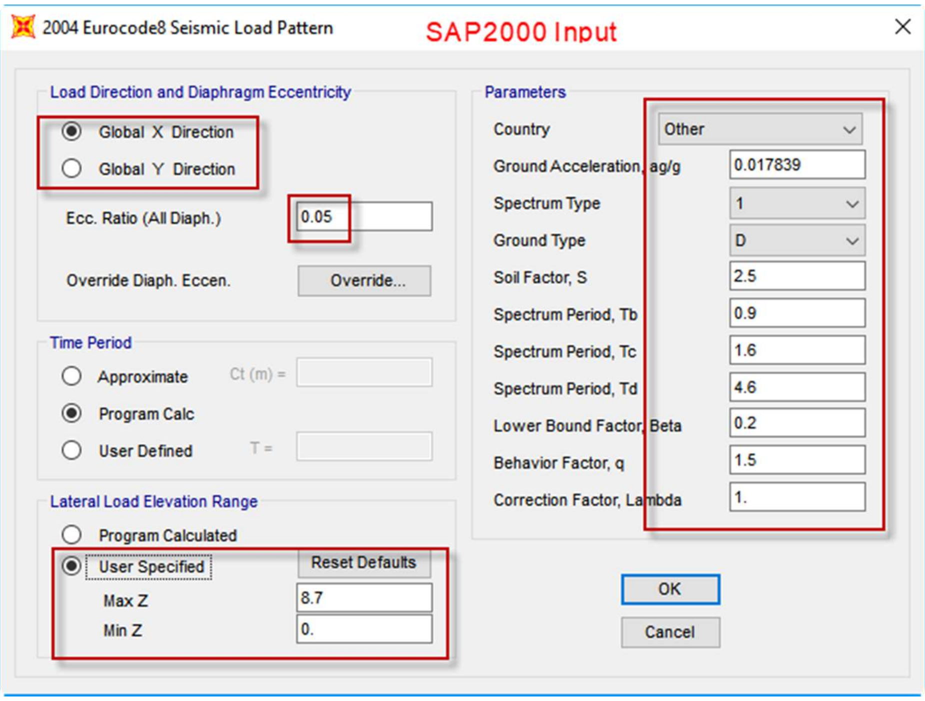
Equivalent Lateral Force Method can also be used as a reference for verifying/checking dynamic seismic analysis results such as RSA.

To define a static seismic load pattern, click on to **Define>Load Patterns…** Select “Seismic” as the type, and select “EUROCODE8 2004” in Auto Lateral Load.




Modify the static seismic load pattern accordingly:






An important thing to note is that the value required for Ground Acceleration is in terms of **ag/g**, where $\mathbf{a_g}$ = $a_{gR}$ x Importance Factor, and **g** refers to gravitational acceleration (9.81 m/s$^2$).

Three options are provided for the building period to be used in calculating the automatic seismic loads as per EC8. These are Approximate, Program Calculated, and User Defined.

In using **Approximate** period, the program will calculate the fundamental period based on EN1998-1 Eq. 4.6.

If **Program Calculated** is chosen, the program start with the period of the mode calculated to have the largest participation factor in the direction that loads are being calculated (X or Y).

For the input the Story/Elevation range data, specify a top story/maximum elevation and a bottom story/minimum elevation. This specifies the elevation range over which the automatic static lateral loads are calculated. In most instances, the top elevation would be specified as the uppermost level in the structure, typically the roof in a building.

The bottom elevation typically would be the base level, but this may not always be the case. For example, if a building has several rigid below-grade levels and it is assumed that the seismic loads are transferred to the ground at ground level, it would be practical to specify the bottom elevation to be above the base level.

Note that no seismic loads are calculated for the bottom story/minimum elevation and below.

Specifying 0.05 (5%) in the eccentricity ratio input will satisfy EC8 requirements regarding minimum accidental torsion effect that need to be considered. The eccentricity options have meaning only if the model has diaphragms—the programs ignore eccentricities where diaphragms are not present.

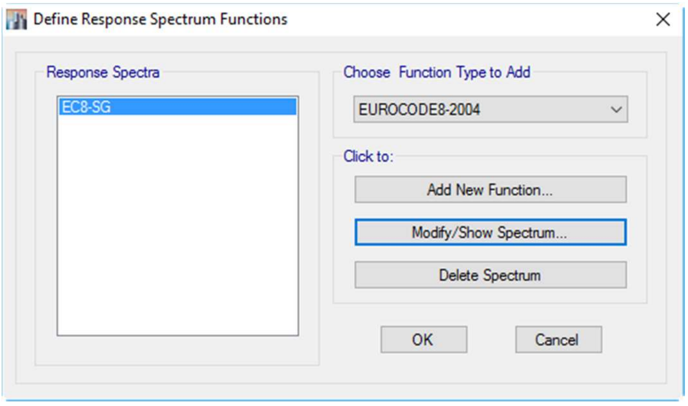
## VI. Defining Response Spectrum Function and Load Case

RSA method is suitable to be used for Irregular buildings. In this dynamic analysis, building irregularity and dynamic effects are both accounted.

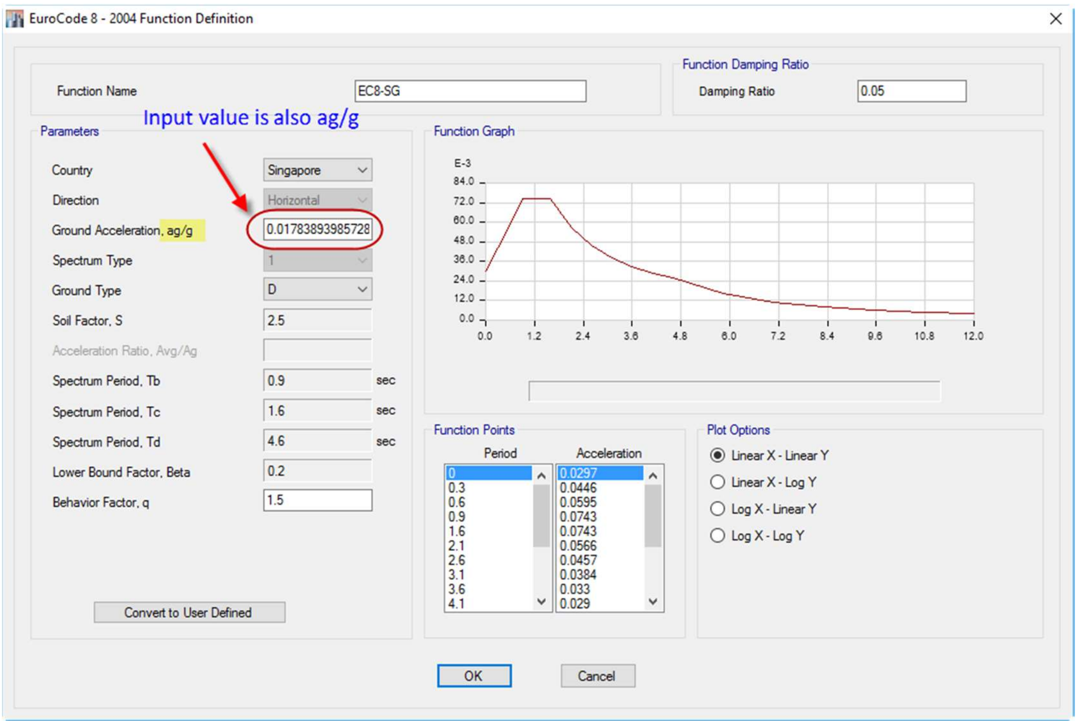
Generally, RSA method is used to find the maximum/peak response of the structure to a certain dynamic loading wherein the "Sign" (direction) is not relevant.

In performing RSA, response spectrum function will be defined as per code.

Click on **Define>Functions>Response Spectrum…** Select EUROCODE8-2004 under Function Type to Add, and click Modify/Show Spectrum...




Define the response spectrum function using similar values as that of in static seismic load pattern definition.



Next, define an RSA load case, click on **Define>Load Case…**