FS2000

FS-Seismic Load Generator

Advanced Structural Analysis
for Windows
(c) A.E.S. Ltd 1988,2020

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1.0 Introduction

FS-Seismic is a load generator that interfaces with FS2000 for the generation of structural loads in accordance with:

- UBC 1997
- IBC 2009
- ASCE 7-16
- EC8 EN 1998-1:2004+

The equivalent lateral static lateral load method is adopted.

A base load case is created which is used to define the mass distribution within the structure. Vertical forces in this load case are converted to masses using a defined global gravitational constant. This enables appropriate in-situ load case(s) to be also used for seismic analysis.

The user inputs the appropriate code coefficients i.e. Zone factors etc. which are used to evaluate the magnitude of the seismic equivalent lateral load. The fundamental period of the structure is evaluated using the Rayleigh method using the mass distribution obtained from the definition load case.

The loading may be applied in any direction.

The load cases produced are standard FS2000 load cases, they may be combined in post-processing to give the structural loads appropriate to the design requirements and the configuration of the structure.

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2.0 Creating Definition Load Cases

The inertial masses within the structure are established from a definition load case created within the loads module of the post-processor of FS2000. The following describes how the loads from a definition load case are interpreted by FS-Seismic.

2.2 Structure Self Weight

Distributed masses due to element self weight will be taken into account using the density of the element and the gravitational constants defined in the definition load case.

2.3 Nodal Forces and Masses

If nodal masses are defined at nodes these are simply taken to be concentrated masses at the respective node. Nodal forces in the Y direction will be converted to nodal masses by taking the absolute values of the force and dividing by the user defined gravitational constant.

Forces in other directions will be ignored.

Do not apply both Y forces and masses unless for some reason these are required to be combined.

2.4 Element Distributed Loads

Element distributed loads in the Y direction will be converted to distributed masses. This done by taking the absolute values of the Y force and dividing by the user defined gravitational constant.

Forces in other directions will be ignored.

2.5 Element Mid Span Point Loads

Element mid span point loads in the Y direction will be converted to concentrated masses. This done by taking the absolute values of the Y force and dividing by the user defined gravitational constant.

Forces in other directions will be ignored.

2.6 Units

The only unit dependent input is that used to convert load to masses within the mass definition case.

In the SI sytem this would be 9.81 in the US system this would be 386.

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3.0 Background Theory

3.1 Fundamental Period

The fundamental period period is a user defined value and can be evaluated using FS2000's Eigen frequency solutions or using this code checker which employs the

Rayleigh method using a lumped mass distribution and the static lateral deflection shape is used to evaluate the fundamental period. The mass distribution is defined in the Definition Load (mass) case and would be identical to that use in an Eigen solution

This is Method B in the UBC code.

The ASCE code does have some additional requirements regarding the period to be used.

3.1 UBC - Uniform Building Code

Total Lateral Base Shear = V = Cv.I /(R.T).W   Eqn 30-4

where

Cv = Seismic Coefficient from Table 16-R (0.06 - 1.92)

I = Importance Factor from Table 16-K (1 to 1.25)

R = Strength Coefficient Table 16-N (2.2 to 8.5)

T = Fundamental Period (seconds)

W = Total Seismic Dead Load

Maximum Lateral Base Shear Limit= 2.5Ca.I /R.W   Eqn 30-5

Ca = Seismic Coefficient from Table 16-Q (0.06 - 0.54)

Minimum Lateral Base Shear Limit= 0.8Z.Nv.I /R.W   Eqn 30-6

Z = Seismic Zone Factor from Table 16-I (0.075 to 0.4)

Nv = Seismic Coefficient from Table 16UBC - -T (1.0 - 2.0)

The Vertical Distribution of base shear complies with the following

V = Ft + Fi

Ft = Concentrated load applied at the top of the structure

Ft = 0.07 T.V

Ft = 0 if T<=7secs

Ft is limited to 0.25V

Fx = (V - Ft) w.h / $\sum$w.h

3.2 IBC - International Building Code

Total **Lateral Base Shear** = V = Cs..W

Cs = S/(R/I)

R = Ductility Factor

I = Importance Factor

Cs = Seismic Response Coefficient = Sa (shown below)

Cs >= 0.01

For cases where S_L >0.6g Cs>= $0.5S_L$ / (R/I)

The **Vertical Distribution** of base shear complies with the following

Fx = V. $w.h^k / \sum w.h^k$

Lateral Seismic Response Coefficient (Sa)

S_{DS} = the design spectral response acceleration parameter at short periods

S_{D1} = the design spectral response acceleration parameter at 1-s period

T = the fundamental period of the structure, s

T_L = long-period transition period (s)

$$S_{MS} = F_a S_s$$

$$S_{M1} = F_v S_1$$

$$S_{DS} = \frac{2}{3} S_{MS}$$

$$S_{D1} = \frac{2}{3} S_{M1}$$

For periods less than T_L $\quad S_a = S_{DS}$

For periods less than T_L , lower of Sa and S_{DS} $\quad S_a = \frac{S_{D1}}{T}$

For periods greater than T_L lower of Sa and S_{DS} $\quad S_a = \frac{S_{D1} T_L}{T^2}$

3.3 ASCE 7

Total **Lateral Base Shear** = V = Cs..W

Cs = S/(R/I)

R = Ductility Factor

I = Importance Factor

Cs = Seismic Response Coefficient = Sa (shown below)

Cs >= $0.044S_{DS}$

Cs >= 0.01

For cases where S_L >0.6g Cs>= $0.5S_L$ / (R/I)

The **Vertical Distribution** of base shear complies with the following

Fx = V. $w.h^k / \sum w.h^k$

Determination of **Fundamental Period**

This code defines limit on the use of Tc for building type structures

If Tc > Cu.Ta use Cu.Ta

If Tc < Ta use Ta

IF Ta < Tc < Cu.Ta use Tc

$$T_a = C_t\, h_n^x$$

Design Spectral Response Acceleration Parameter at 1 s, S_{D1}	Coefficient C_u
≥ 0.4	1.4
0.3	1.4
0.2	1.5
0.15	1.6
≤ 0.1	1.7

Lateral Seismic Response Coefficient (Sa)

S_{DS} = the design spectral response acceleration parameter at short periods

S_{D1} = the design spectral response acceleration parameter at 1-s period

T = the fundamental period of the structure, s

$$T_0 = 0.2\frac{S_{D1}}{S_{DS}}$$

$$T_S = \frac{S_{D1}}{S_{DS}} \text{ and}$$

T_L = long-period transition period (s)

$$S_{MS} = F_a S_s$$

$$S_{M1} = F_v S_1$$

$$S_{DS} = \frac{2}{3} S_{MS}$$

$$S_{D1} = \frac{2}{3} S_{M1}$$

For periods less than T0

$$S_a = S_{DS}\left(0.4 + 0.6\frac{T}{T_0}\right)$$

For periods greater than Ts and less than or equal to TL

$$S_a = \frac{S_{D1}}{T}$$

For periods greater than TL

$$S_a = \frac{S_{D1} T_L}{T^2}$$

3.4 EC8

In the program the Sd(T).λ /g are identified as the Lateral Load Coefficient

$$F_b = S_d(T_1) \cdot m \cdot \lambda \tag{4.5}$$

$$0 \leq T \leq T_{\mathrm{B}} : S_{\mathrm{d}}(T) = a_{\mathrm{g}} \cdot S \cdot \left[\frac{2}{3} + \frac{T}{T_{\mathrm{B}}} \cdot \left(\frac{2,5}{q} - \frac{2}{3}\right)\right] \tag{3.13}$$

$$T_{\mathrm{B}} \leq T \leq T_{\mathrm{C}} : \; S_{\mathrm{d}}(T) = a_{\mathrm{g}} \cdot S \cdot \frac{2,5}{q} \tag{3.14}$$

$$T_{\mathrm{C}} \leq T \leq T_{\mathrm{D}} : S_{\mathrm{d}}(T) \begin{cases} = a_{\mathrm{g}} \cdot S \cdot \dfrac{2,5}{q} \cdot \left[\dfrac{T_{\mathrm{C}}}{T}\right] \\ \geq \beta \cdot a_{\mathrm{g}} \end{cases} \tag{3.15}$$

$$T_{\mathrm{D}} \leq T : \quad S_{\mathrm{d}}(T) \begin{cases} = a_{\mathrm{g}} \cdot S \cdot \dfrac{2,5}{q} \cdot \left[\dfrac{T_{\mathrm{C}} T_{\mathrm{D}}}{T^2}\right] \\ \geq \beta \cdot a_{\mathrm{g}} \end{cases} \tag{3.16}$$

where

a_{g}, S, T_{C} and T_{D}	are as defined in **3.2.2.2**;
$S_{\mathrm{d}}(T)$	is the design spectrum;
q	is the behaviour factor;
β	is the lower bound factor for the horizontal design spectrum.

NOTE The value to be ascribed to β for use in a country can be found in its National Annex. The recommended value for β is 0,2.

$$a_{\mathrm{g}} = \gamma_1 . a_{\mathrm{gR}}$$

T_{B}	is the lower limit of the period of the constant spectral acceleration branch;
T_{C}	is the upper limit of the period of the constant spectral acceleration branch;
T_{D}	is the value defining the beginning of the constant displacement response range of the spectrum;
S	is the soil factor;

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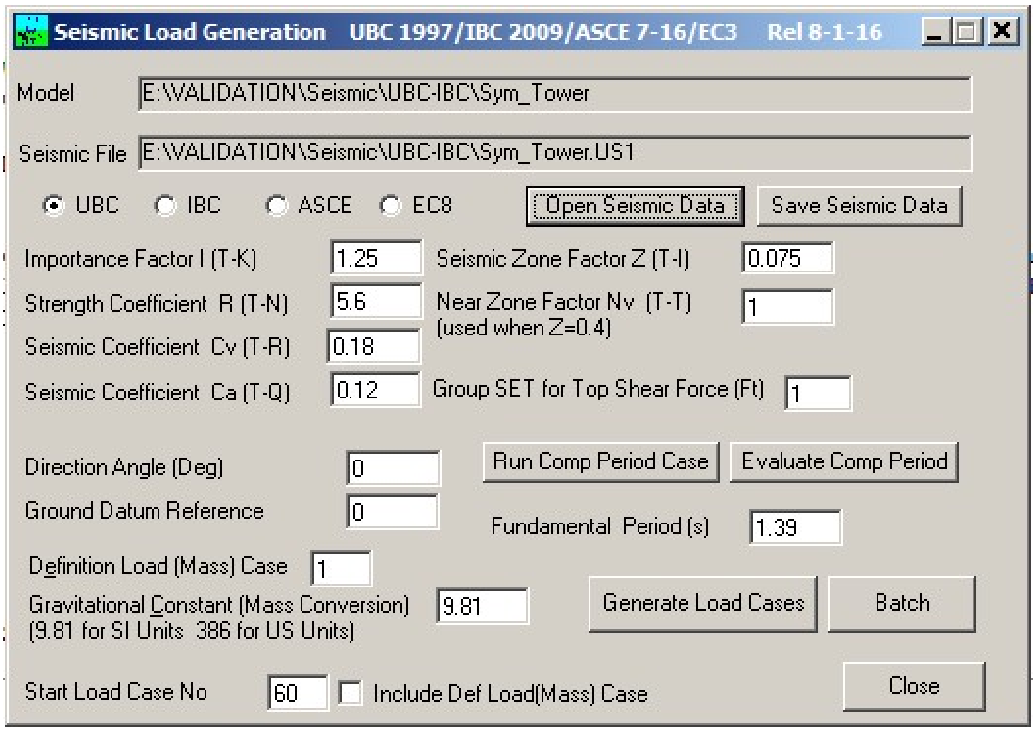
4.0 Operation

FS-Seismic can be run interactively or by batch operation. For interactive operation it is started from the FS-Seismic icon in the FS2000 windows groups.

When the program has loaded the following input form will become visible.



The **Seismic Code** option buttons are used to select the design code. The code input options change to suit the selected code (see below)

Open Seismic Data & **Save Seismic Data** Buttons

The seismic parameters can be saved or re-loaded using the Open and Save buttons. Seismic data is saved using the file extension '.US"n"' , where "n" is an ID number. Data under this file extension will be archived with the model.

Fundamental Period in seconds. This can be evaluated by the FS-Seismic by Mehod B or can be evaluated by modal analysis see Sect 4.2.

Group SET for Top Load (Ft) The top load Ft will be distributed equally to all nodes that are assigned to Group 1 in this Group SET. Assign nodes to group SET in FS2000.

Direction Angle (Deg) This input box is used to define the direction of loading. Zero is positive global X axis.

Ground Datum Reference This is used to define the position of ground relative to the model co-ordinate system. (see Appendix 1)

Definition Load Case This is used to define the definition load case (see Sect 2.0)

Gravitational Constant (Mass Conversion) used to convert loads to masses (see Sect 2.0)

Start Load Case - Each time the Generate Load Case button is pressed 3 load cases starting at that number will be created. The Seismic Case is the third.

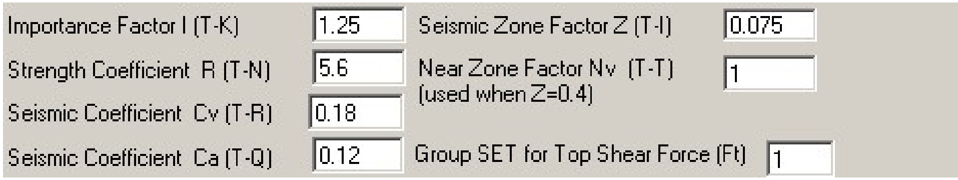
The **Include Def Case** check is used to include/exclude the definition case with/from the Seismic Case.

The **Generate Load Case** button will generated the load cases see Sect 4.1

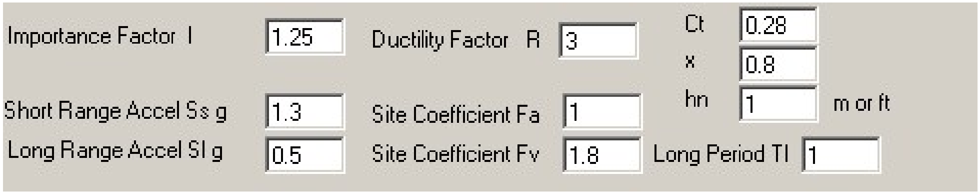
The Run Fundamental Period Case and **Evaluate Fundamental Period** buttons are used to evaluate the fundamental periods in accordance with Method B see Sect 4.2.

Batch Button - See Sect 4.3

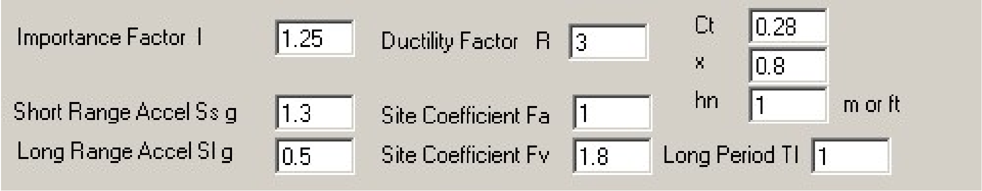
UBC Seismic Design Code Parameters The following input boxes are used to define the appropriate design factors (see Sect 3).



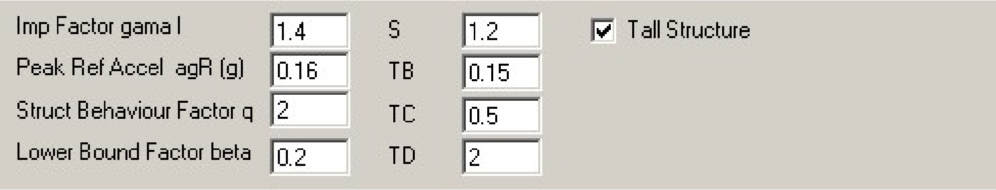
IBC Seismic Design Code Parameters The following input boxes are used to define the appropriate design factors (see Sect 3).



IBC Seismic Design Code Parameters The following input boxes are used to define the appropriate design factors (see Sect 3).



EC8 Seismic Design Code Parameters The following input boxes are used to define the appropriate design factors (see Sect 3).



The **Tall Structure** option indicates that the reduced effective mass is to be implemented

Note that the reference ground acceleration (**agR)** is defined in terms of a g force. i.e. **agR/g**

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4.1 Creating the Load Cases

When the **Generate Load Case** button is pressed three load cases will created. The load case numbering will start at the number entered in the Start Load Case box. If the start load case was defined as 60 then the following cases would be created.

L60 Static - Definition Case

L61 Fundamental Case

L62 Seismic Case

The Static Definition Case is a duplicate of the definition case but with only the vertical forces included.

The Fundamental Case is a special case that can be used to evaluate the Fundamental Period. This load case is similar to the Static definition case except that the loads are applied laterally. Note that this load case is only used for fundamental period elevation, it has no physical significance.

The Seismic Case is the load case with the equivalent static lateral seismic loads. This load case may also include the vertical loads of the static definition case if the include box is activated.

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4.2 Evaluating the Fundamental Period

If the Fundamental Period load case has been created (**Generata Load Cases** button) it may used to evaluate the fundamental period of the structure.

This is done by first pressing the **Run Fundamental Period Case** button to run the load case. This creates the static lateral deflection case corresponding to the distributed masses.

When the **Evaluate Fundamental Period** is pressed the fundamental period will be evaluated and printed to the screen. The Rayleigh method is then used to evaluate the fundamental period. This uses a lumped mass approach. This is Method B in the UBC code.

An alternative to using Rayleigh method is to use the FS2000 Frequency analysis to evaluate the fundamental modes of vibration.

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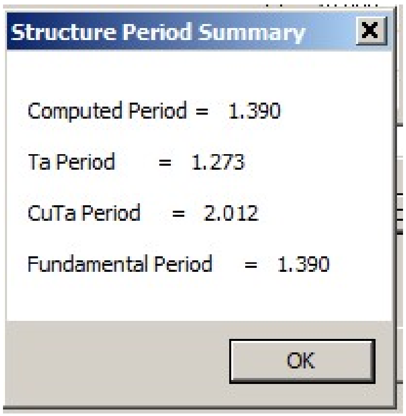
The following sequence has to be adopted to evaluate the period. It is only dependent upon the mass case.

- Click the **Generate Load Cases** button - This created the lateral load case to be used by the Rayleigh method based on the **Definition Mass Case**.
- Click the **Run Comp Period Case** button - This evaluated the displacements for the Rayleigh method.
- Click the **Evalute Comp Period** button - This evaluates the structural period using the Rayleigh method.

The results will be be displayed in a dialog box.

In the case of the ASCE code the output will show the Period to be used based on code requirements otherwise the just the evaluated period.



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4.3 Batch (Command Line) Operation

Providing that an appropriate ,modename>**'.USn'** exists the program may be operated using command line operation.

SEISMIC C1/C2/C2/

C1 Seismic Data File ID (0-9)

C2 Definition Load Case Number

C3 Start Load Case Number

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4.4 Data Files Created

The only files are unique to FS-Seismic are the definition data files that contains the seismic data.

These files have the model filename with the extension **'.USn'.**

Note that the three load cases created are generated load cases. They should NOT be loaded into the loads module, re-saved or otherwise up-dated manually.

The **Batch** button will append the current settings to the Seismic command line to the <ModelName>.BRM file.

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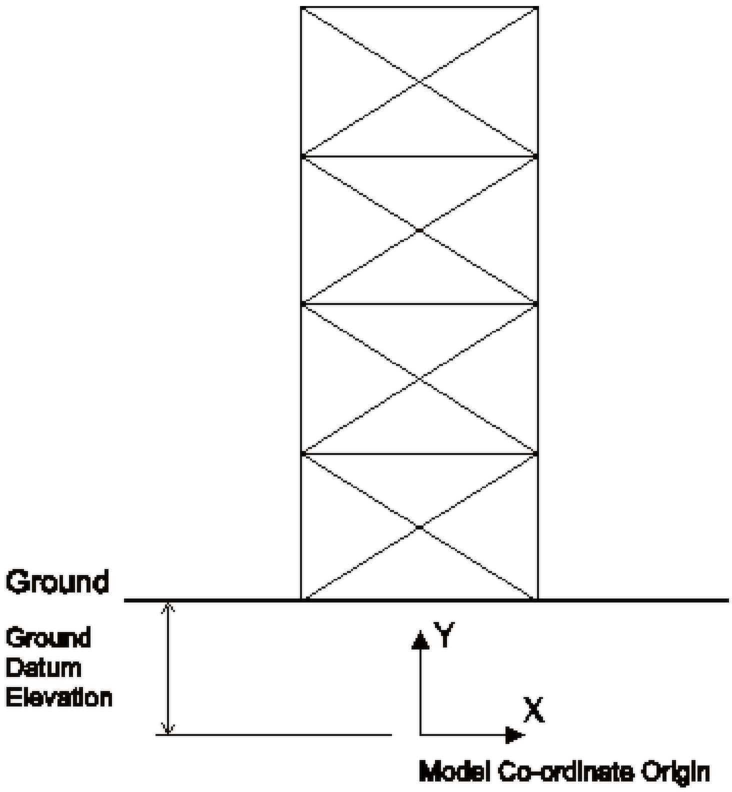
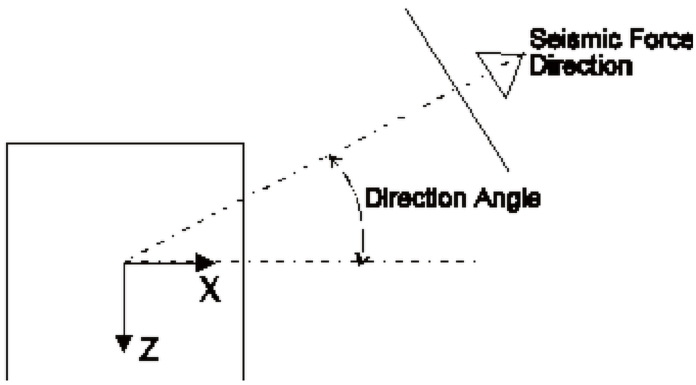
APPENDIX A - Data Files Created





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