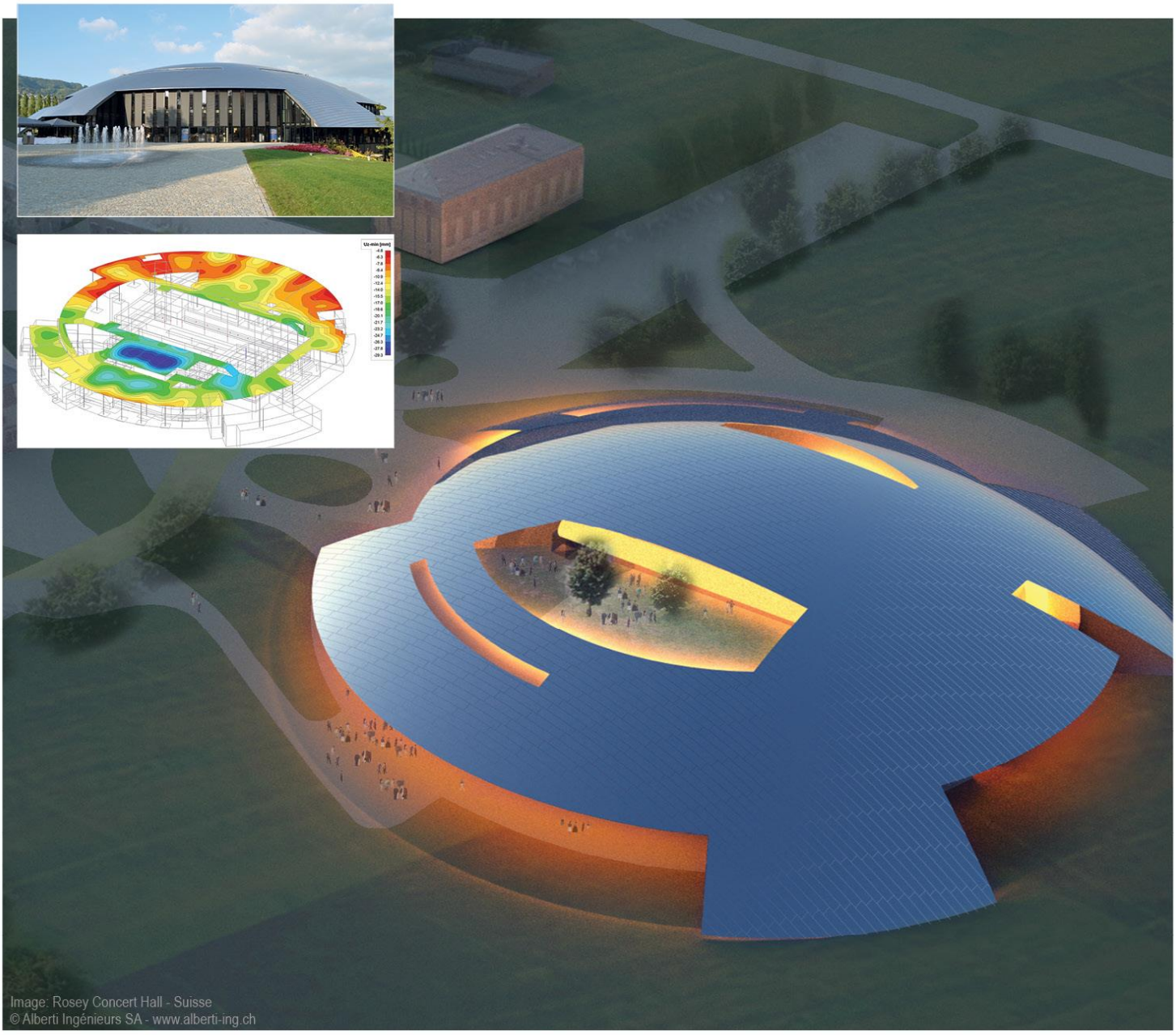
SCIAENGINEER



Manual

Equivalent Lateral Force Procedure

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Nemetschek Scia Offices

Latest version is available on: http://nemetschek-scia.com/en/contact/offices

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General Information

Scia Engineer Support

If you need assistance with the software, you can contact the Scia Engineer support service in the following manners:

By e-mail

Send an e-mail to support@scia-online.com with a description of the problem and the concerning *.esa file, and mention the number of the version you are currently working with.

By telephone

From Belgium: +32 13 350310

From the Netherlands: +31 26 3201230

From the USA: 443 542 0637

Via the Scia Support website

http://www.Scia-online.com/en/online-support.html

Helpful Links

Link to Tutorials

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Link to eLearning

http://www.Scia-online.com > Support & Downloads > eLearning

Link to Demo version

http://www.Scia-online.com > Support & Downloads > Secured Downloads > input username and password > Service Packs > Scia Engineer > Setup – Scia Engineer

Link to User Interface Video

http://www.youtube.com/watch?v=t6fgRJ90FE0&list=PL0OvQw2kgGq64GwSUbuzxvvS9DyKGtUn3

Introduction & Background

The purpose of this manual is to document the implementation of the Equivalent Lateral Force (ELF) Procedure in Scia Engineer 15. The concept employed in the ELF Procedure is to place static loads on a structure with magnitudes and direction that closely approximate the effects of dynamic loading as caused by seismic events (earthquakes). Concentrated lateral forces due to dynamic loading have a tendency to occur at building floor and roof stories where the concentration of mass is the greatest. Additionally, these concentrated lateral forces are typically larger at the higher elevations of the structure. This is why the largest lateral displacements of a structure occur at the top level. These effects can be approximated and thus are modelled using the Equivalent Lateral Force Procedure as described in Section 12.8 of ASCE 7-10.

This manual will discuss the Equivalent Lateral Force Procedure, its implementation within Scia Engineer 15 as well as some benchmarked examples derived from the methods prescribed in the code.

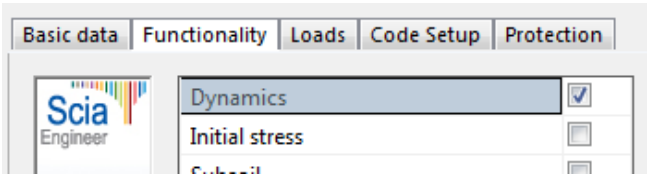
Implementation in Scia Engineer

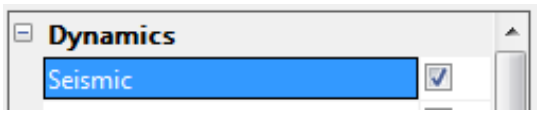
Section 12.8 of ASCE 7-10 outlines the necessary requirements for use of the Equivalent Lateral Force Procedure. The end goal of this procedure is the calculation of a structures base shear, as well as the vertical distribution of seismic forces to various levels of the structure. These loads can then be applied to the structure and used for seismic load analysis, in lieu of performing a dynamic analysis.

For seismic loading, it is possible to use Scia Engineer to perform dynamic (modal) analysis as well. For more information on this topic, download the Dynamics manual for the Nemetschek Scia website.

Project Settings

The Equivalent Lateral Force Procedure utilizes the **Seismicity** load type to create the lateral loading. Therefore, in order to utilize this functionality, the user must enable **Dynamics** and **Seismic** from the **Project Settings, Functionality** tab.

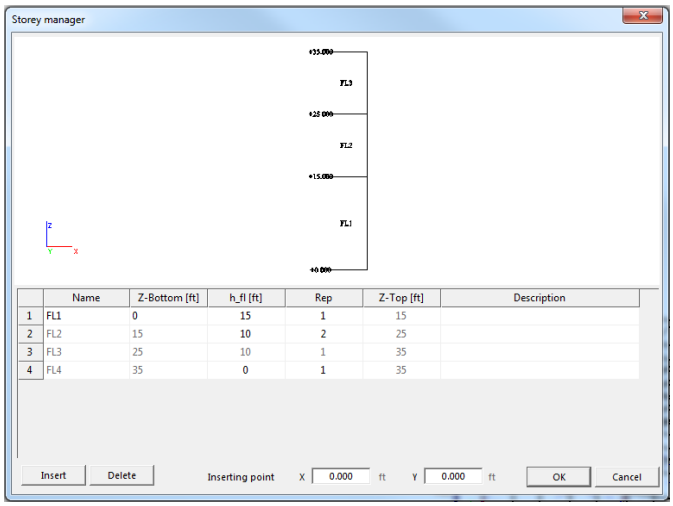




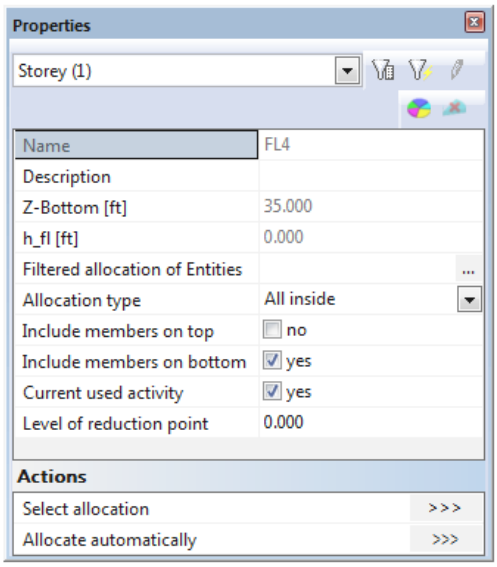
Creating Geometry and Adding Loads/Masses

With the proper functionality enabled, the necessary model components (columns, beams, slabs, walls, etc.) can be added. Once these items have been created, it is also required that stories be added to the model. In Scia Engineer, stories are used in conjunction with the Improved Reduced System method of dynamic analysis (which will be discussed later) to complete the Equivalent Lateral Force Procedure.

To add stories to the model, open the Line grid and storeys functionality from the main service tree and double click on Storeys. Next, add the stories that correspond to the levels of the structure.



Once the stories have been added, it is necessary to assign the structural members to their appropriate story. This is done so that the self weight and masses of the structure get properly accounted for during the analysis procedure. To do this, select one of the stories in order to open the properties for the element. Within the properties, there are various options which modify how members are accounted for in stories. Items can be allocated to stories either manually or automatically, additionally the settings for the way items are allocated can be modified. In most cases, it is sufficient to select **Allocate Automatically** from the **Actions** in order to assign the members to stories. Once the members have been allocated the line grids and stories service can be closed.

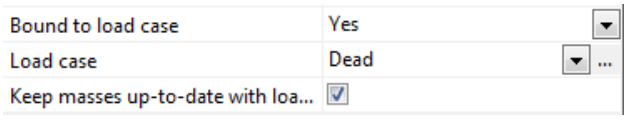


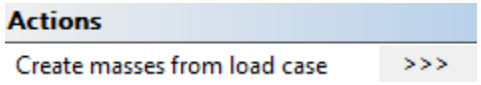
For more information on stories and how allocation is utilized, visit the online help for more information concerning allocation.

Once the model geomerty is complete, loading for use in a linear analysis is added. These loads including self-weight, dead load as well as other loading can added to the structure through the Load service.

Once loads have been added, it is possible to create the masses that are necessary for the seismic analysis. In Scia Engineer, there are two different ways to add masses to a given structure. First, it is possible to utilize the Masses functionality within the Dynamics service to create individual surface, line or point masses. More appropriately, it is possible to automatically create masses directly from applied loads.

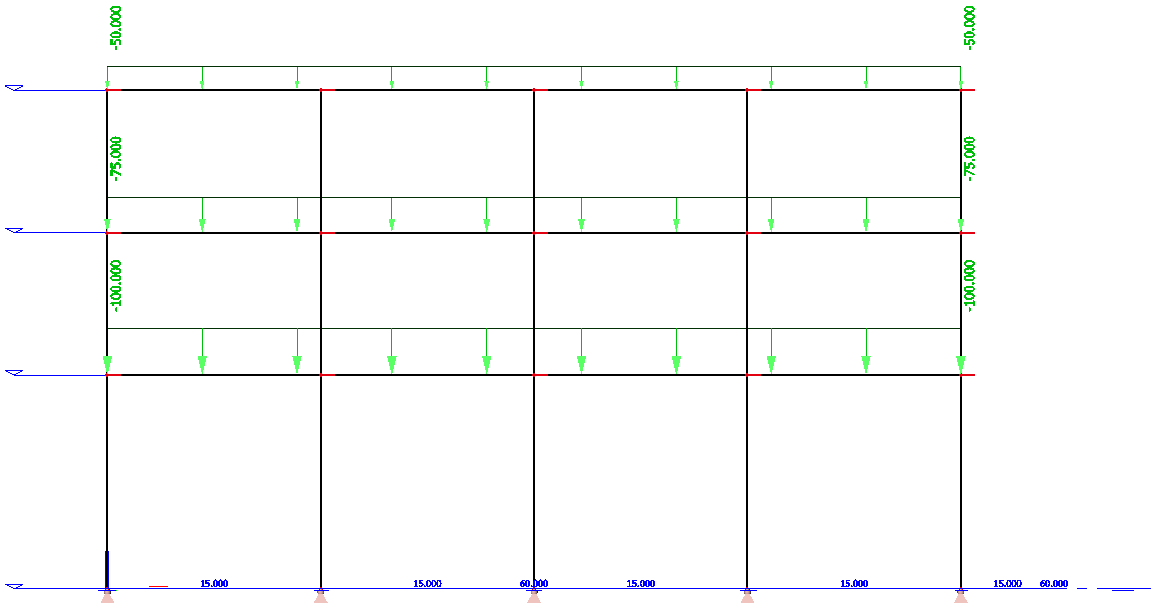
To do this, open the Mass groups functionality from within the **Dynamics** service. New mass groups can then be created just like new load cases are created. When adding a new mass group, it is possible to bind the mass group to a corresponding load case, while also selecting that the mass group should update whenever changes are made to the load case. Once the proper selections are made, the Action button for **Create masses from load case** is selected and the corresponding masses are added to the model.





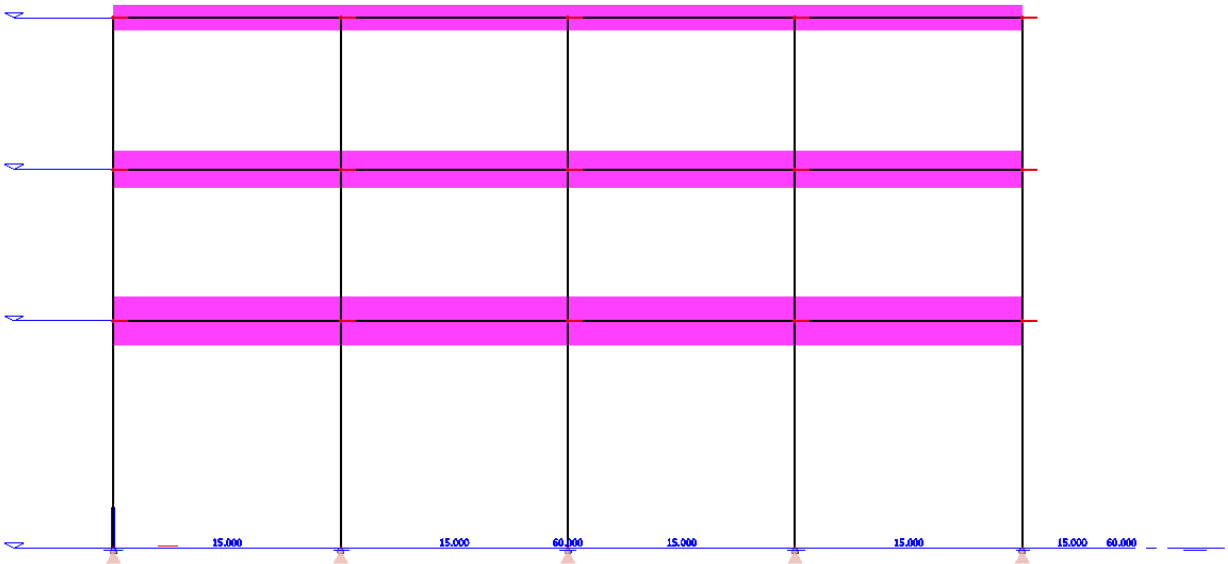
1. Surface load

Name	Dir	Type	Value [lbf/ft²]	2D member	Load case	System	Loc
SF1	Z	Force	-50.000	S1	Dead	LCS	Length
SF2	Z	Force	-75.000	S2	Dead	LCS	Length
SF3	Z	Force	-100.000	S4	Dead	LCS	Length



2. Surface mass

Name	Mass group	M [lb/ft²]	Koeff mx	Koeff my	Koeff mz	2D member
SM1	Dead	50.0	1	1	1	S1
SM2	Dead	75.0	1	1	1	S2
SM3	Dead	100.0	1	1	1	S4

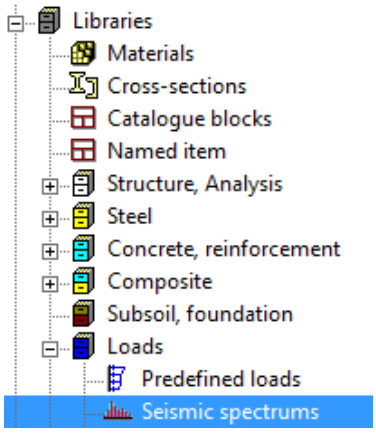


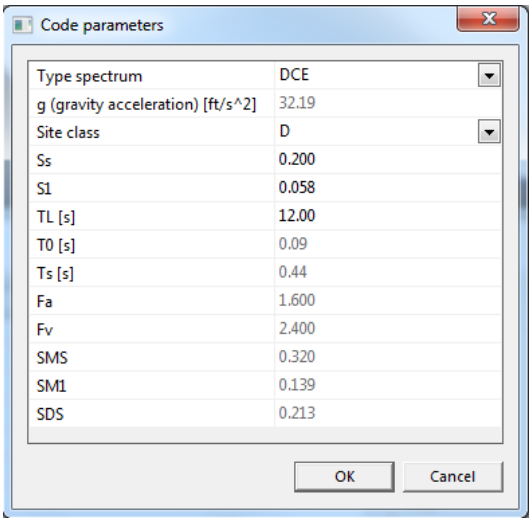
Once the masses are added to the model, a Combination of mass groups should be created in order to combined all of the necessary masses that will be used for the Equivalent Lateral Force Procedure analysis.

Response Spectrum & Seismic Load Cases

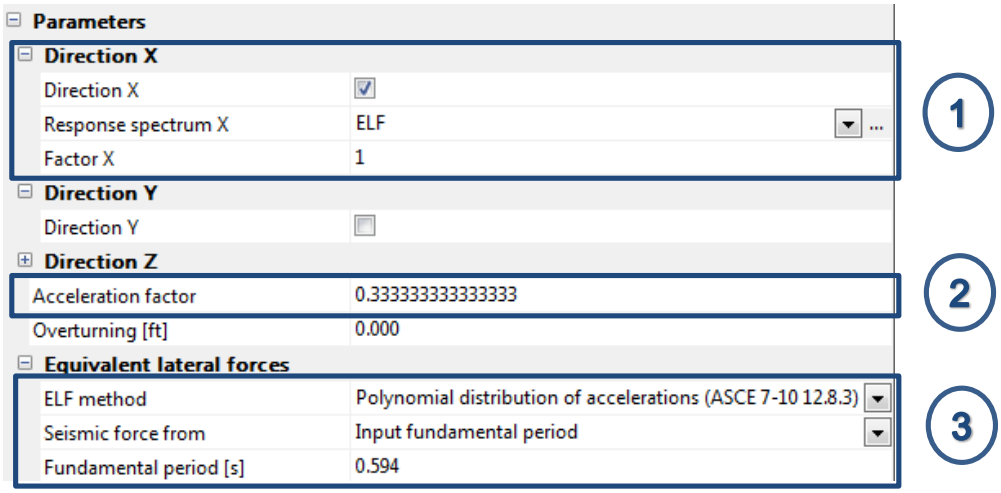
With the model complete and masses added to the structure, the next step in the Equivalent Lateral Force Procedure within Scia Engineer is to create the seismic response spectrum and corresponding seismic load cases.

The seismic response spectrum can be defined from the **Libraries** service under the **Loads** item. When the seismic spectrum dialogue box opens, options for the spectrum name, drawing type (period or frequency) and Input type are available. The input type should be set to the code in which the project is built (for ASCE 7 use **IBC**). After the input type has been selected, the **code parameters** can be established. For the ASCE 7 spectrum the following variables are required: site class, short period acceleration parameter (S_s), one second period acceleration parameter (S_1) and the long period (T_L).





Once the code parameters of the seismic spectrum have been defined the spectrum can be included in the seismic load cases. To set up the seismic load cases, open the Load Cases functionality from the main service tree and create two new load cases for the seismic load applied in the X & Y directions. Each of these load cases should have the **load type, static equivalent** and the **specification** set to **seismicity**. This will allow for the seismic spectrum to be used to define the loading of the Equivalent Lateral Force Procedure.



Within the parameters of the static equivalent load type, the following variables should be considered:

1. A **direction** should be selected depending on which direction the load is going to be applied. For each load case, only one direction should be selected. Once a direction is selected (by enabling the checkbox) the appropriate **response spectrum** should be selected. Additionally, the magnitude of the spectrum can be modified using the **factor** variable. In most cases, the variable should remain at 1.

2. Part of the Equivalent Lateral Force Procedure as defined in Section 12.8 of the ASCE 7 is the calculation of the seismic response coefficient, C_s. This value is then multiplied by the effective seismic weight of the structure, W to calculate the structures seismic base shear, V. In order to appropriately determine the value of C_s, the response modification factor R, must be included. In Scia Engineer, this factor is known as the **acceleration factor** and it can be calculated by taking the inverse of the value found in Table 12.2-1 of ASCE 7.

3. Scia Engineer offers multiple methods for the determination of equivalent lateral forces including the polynomial distribution which is required by ASCE 7. Additional methods include a linear distribution as well as a distribution of accelerations from a specific eigenmode. It is also necessary to select which portion of the spectrum the force is generated from. Options for this include the max acceleration of the spectrum or according to the fundamental period of the structure. In ASCE 7 the approximate fundamental period, T_a is calculated using the following equation:

$$T_a = C_t h_n^x$$

   where h_n is the structural height and C_t and x are coefficients which correspond to specific structure types as defined in Table 12.8-2 of ASCE 7.

Once both the X & Y direction seismic load cases are established the linear analysis can be executed.

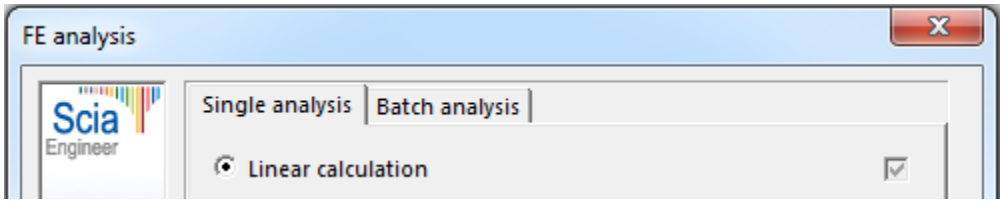
Analysis & Results

Before any calculation in Scia Engineer is executed, it is important to review the Solver setup information located in the **Calculation, mesh** service. For the Equivalent Lateral Force Procedure, it is necessary to verify that that the checkbox for Use IRS (Improved Reduced System) method is active.

Dynamics	
Type of eigen value solver	Polynomial
Number of eigenmodes	4
Use IRS (Improved Reduced System) method	☑

The IRS method takes into account both the stiffness and mass matrix during the condensation process. This allows for the mass in the model to be “grouped” at the floor levels so that the Equivalent Lateral Force Procedure can be accurately implemented.

Once the solver settings have been verified, the linear Calculation should be executed and the results of the model can be explored.



To access the appropriate results, open the Results functionality found in the main service tree and expand the **Stories** result type. Using Summary results the required output for the Equivalent Lateral Force Procedure can be displayed by selecting the appropriate load case and value (F_{tot}). Once the properties of the result are set up, the **Refresh** action button can be selected and the results will be available on the model. Additionally, by selecting the **Preview** action button the full results including the masses, period, distribution factor, forces per story and total base shear are available.

Summary storey result

Storey data:
Linear calculation, Extreme: Member, System: Principal
Selection: All
Load cases : EX_ELF
Equivalent Lateral Forces (ELF) settings

ELF method	Polynomial distribution of accelerations (ASCE 7-10 12.8.3)
Seismic force from	Input fundamental period
Fundamental period [s]	0.59
Distribution factor k	1.05
Mode shape	3

Equivalent Lateral Forces (ELF) per storey

Name	M [kips]	Zg [ft]	Fx [kip]
FL1	0.000	0.000	**0.00**
FL2	575.634	15.000	**18.41**
FL3	668.848	25.000	**36.52**
FL4	387.275	35.000	**30.08**
Total	**1631.757**		**85.00**

If required, this information can also be made available in the Engineering report.

Example

The Excel table below was created utilizing the information and equations found in section 12.8 of ASCE 7-10 for the calculation of seismic base shear and the vertical distribution of seismic forces.

Total Building Weight (k)		Seismic Coeffient	Building Period	Distribution Exponent	North/South Seismic Base Shear	East/West Seismic Base Shear
X Direction	1631.8					
Y Direction	1631.8	0.0521	0.594	1.047	85.0	85.0

Level Information				North/South Distribution			East/West Distribution		
Level	Height (ft)	N/S Weight (k)	E/W Weight (k)	WH^K	C_{VX}	Fx (k)	WH^K	C_{VX}	Fx (k)
Roof	35	387.3	387.3	16019.86	0.354	**30.1**	16019.86	0.354	**30.1**
2nd Floor	25	668.8	668.8	19452.285	0.430	**36.5**	19452.285	0.430	**36.5**
1st Floor	15	575.6	575.6	9806.4989	0.217	**18.4**	9806.4989	0.217	**18.4**
				0	0.000	**0.0**	0	0.000	**0.0**
				0	0.000	**0.0**	0	0.000	**0.0**
				0	0.000	**0.0**	0	0.000	**0.0**
				0	0.000	**0.0**	0	0.000	**0.0**
				0	0.000	**0.0**	0	0.000	**0.0**
				0	0.000	**0.0**	0	0.000	**0.0**
				0	0.000	**0.0**	0	0.000	**0.0**
Totals				45278.6	1.0	85.0	45278.643	1.0	85.0

The below results from the Scia Engineer output indicate the values of the distribution factor (exponent), fundamental period and total building weight are exactly the same. Additionally, the results for the story shears, story masses and overall base shear are also the same. Therefore, it is reasonable to assume that Scia Engineer is appropriately performing the calculations and methods as detailed in ASCE 7-10 Section 12.8.

Summary storey result

Storey data:
Linear calculation, Extreme: Member, System: Principal
Selection: All
Load cases : EX_ELF
Equivalent Lateral Forces (ELF) settings

ELF method	Polynomial distribution of accelerations (ASCE 7-10 12.8.3)
Seismic force from	Input fundamental period
Fundamental period [s]	0.59
Distribution factor k	1.05
Mode shape	3

Equivalent Lateral Forces (ELF) per storey

Name	M [kips]	Zg [ft]	Fx [kip]
FL1	0.000	0.000	**0.00**
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