Ing. Software
Dlubal

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Add-on Module

RF-DYNAM 2007

Program Description

Am Zellweg 2 D-93464 Tiefenbach

Tel: +49 (0) 9673 9203-0
Fax: +49 (0) 9673 1770
E-mail: info@dlubal.com
Web: www.dlubal.com

Contents

1. Introduction

1.1 Add-on Module RF-DYNAM 2007

Dear users of the RFEM and DYNAM programs,

to introduce our manual, we would like to tell you some important things concerning the RF-DYNAM module and to draw attention to some aspects. It does not matter if you have already become acquainted with any previous versions of this module as our longtime customers or if you see it for the first time - this module was developed with an emphasis on a practical use and during its development we started from a constructive cooperation with our many customers and business partners. Practically, everybody can easily and quickly master the work with this module. Numerous valuable remarks from an everyday design practice has motivated us by now to incessant further development and improvement of the modules DYNAM 4.xx and DYNAM 2000 and certainly fully manifested itself on the final appearance of the RF-DYNAM 2007 module.

RF-DYNAM 2007 starts from Windows standards and by far does not make only an optical component of the main RFEM program. Results of an eigenvector calculation (RF-DYNAM BASIC) and generated equivalent seismic loads (RF-DYNAM ADDITION II) can be incorporated together with graphics into the printout report of the RFEM program. Thus all the results can be suitably and particularly uniformly arranged and organized.

We wish you much success when working with the main program RFEM and its add-on module RF-DYNAM 2007.

Your company DLUBAL ENGINEERING SOFTWARE.

1.2 RF-DYNAM 2007 Team

The following people participated in the development of the RF-DYNAM 2007 module:

Program Coordinators

Dipl.-Ing. Georg Dlubal

Dipl.-Ing. (FH) Matthias Entenmann

Dipl.-Ing. Rafael Ceglarek

Programmers

Dr.-Ing. Jaroslav Lain

Ing. Václav Sýkora

Design of Program, Dialogs and Icons

Dipl.-Ing. Georg Dlubal

MgA. Robert Kolouch

Ing. Jan Miléř

Testing and Technical Support

Dipl.-Ing. Georg Dlubal

Dipl.-Ing (FH) Matthias Entenmann

Dipl.-Ing. (FH) Walter Rustler

Dipl.-Ing. Rafael Ceglarek

Dipl.-Ing. (FH) André Bergholz

Dipl.-Ing. Frank Faulstich

Dipl.-Ing. (FH) René Flori

Dipl.-Ing. (BA) Andreas Niemeier

Ing. Martin Vasek

Bc. Michaela Sobotková

Ing. Petr Míchal

Dipl.-Ing. David Röseler

M. Sc. Dipl.-Ing. (FH) Frank Sonntag

Dipl.-Ing. (FH) Christian Stautner

Dipl.-Ing. (FH) Robert Vogl

Dipl.-Ing. (FH) Anke Voggenreiter

Manuals, Documentation and Translations

Dipl.-Ing. Rafael Ceglarek

Dipl.-Ing. (FH) Robert Vogl

Mgr. Michaela Kryšková

Ing. Petr Míchal

Mgr. Petra Pokorná

2. Installation

2.1 System Requirements

The following minimal configuration (a recommendation is quoted in brackets) makes the condition for the use of RFEM and its add-on module RF-DYNAM:

- Windows WIN 2000/XP/Vista operating system
- 1 GHz (2 GHz) processor
- 512 MB RAM (1024 MB)
- DVD-ROM and 3.5” floppy drive for installation
- 5 GB free space on hard disk, from this about 500 MB for installation
- Graphics card with resolution 1024 x 768 pixels (with Open GL acceleration)

Except for the operating system we do not want to recommend any specific products on purpose, because RFEM and its add-on modules run in principle on all systems that meet the quoted requirements. However, if anyone wants to use RFEM and RF-DYNAM 2007 intensely and effectively, then "the more the better" holds true.

2.2 Installation Procedure

The installation runs automatically after the DVD with RFEM is inserted to the DVD-ROM drive. Regarding the fact that the add-on module RF-DYNAM 2007 is fully integrated to RFEM, its name is not explicitly mentioned during the insallation. However, if you own its license and have an authorization for its use, the module will be automatically installed together with RFEM.

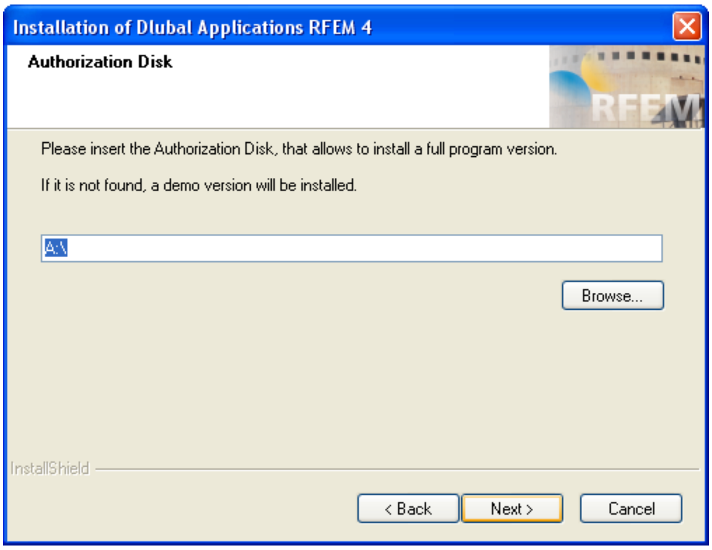


Figure 2.1: Prompt to Insert Floppy Disk with Authorization File

If the authorization CD contains at least one valid license, three following installation options are displayed: [Standard], [Minimum] and [User Defined].
A missing or wrong authorization can be recognized in this way: Only two installation types are available in the menu - [Standard] and [User Defined].

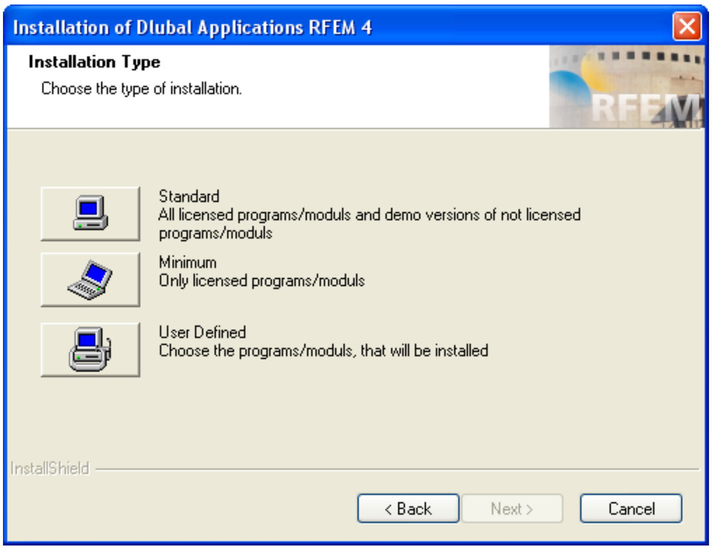


Figure 2.2: Installation Types in Case of Right Authorization

In case of a missing authorization a warning is displayed that the [Demo] version will be installed.

If you choose the [Standard] installation type, a complete application of RFEM and its add-on modules is installed. Programs can be started consequently by clicking on their desktop icons or from the Start menu as a full version, eventually only as a demoversion.

If you choose the [Minimum] installation type only programs whose license is written on an authorization disk are installed. The exception makes RFEM with its add-on modules that are all installed even in case that you don't have an authorization to some modules.

In case of the [User Defined] installation type you can manually select individual programs available on the DVD. Modules which are not directly integrated to RFEM and whose licence you do not have are marked during this installation as [Demo].

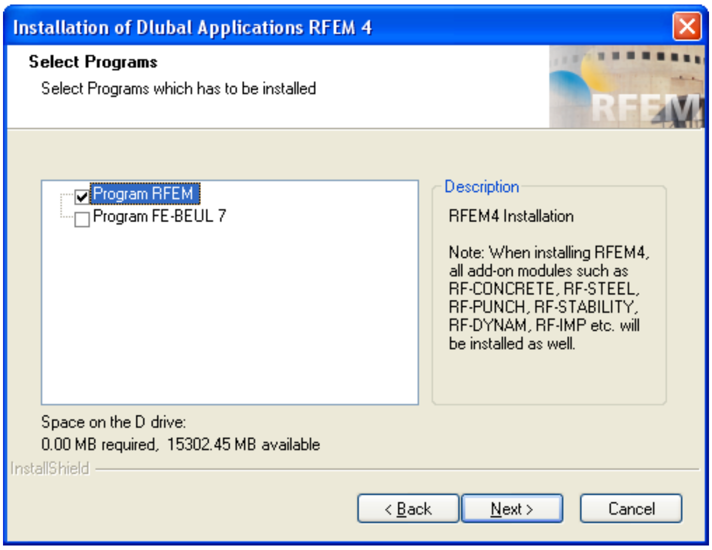


Figure 2.3: User Defined Installation in Case of Valid Authorization

3. Using RF-DYNAM 2007

3.1 Starting RF-DYNAM 2007

It is possible to initialize the add-on module RF-DYNAM 2007 by the command from the RFEM main menu:

Additional modules → Dynamic

or by clicking on the corresponding item in the [**Additional Modules**] folder in the *Data* navigator (on the left on the RFEM work area).

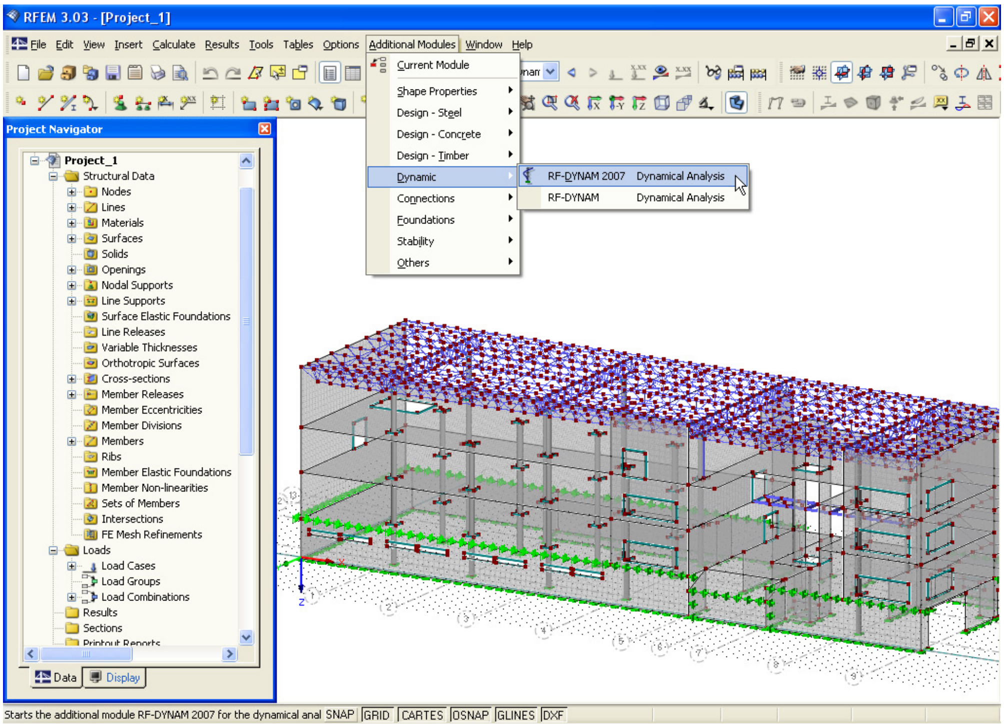


Figure 3.1: Starting RF-DYNAM 2007 Module from Main Menu

3.2 Masks

The masks serve for entering input data to define eigenmodes and later also to display numerical results on the screen.

After starting the RF-DYNAM 2007 module you see the navigator on the left that contains all currently accessible masks. Three pull-down menus *File, Settings* and *Help* are located below the main strip. They contain functions that are described in chapter 3.5.

The masks can be opened either by clicking on the relevant entry in the RF-DYNAM navigator or can be gradually browsed using the keys [F2] and [F3] or the buttons [<<] and [>>]. After clicking on the [Graphic] button the graphic display of results opens where you automatically see the currently selected natural frequency. Detailed information on the display of results can be found in chapter 3.4. You save both input data and results by the [OK] button before quitting the module, while the [Cancel] button serves to exit the module without data saving. You can call up the online help by the button [Help] or by the [F1] function key.

3.3 Input Masks

In the input masks it is necessary to enter all data needed for the calculation of natural frequencies and also for generating equivalent seismic loads (RF-DYNAM ADDITION II) and to set required parameters.

3.3.1 Mask 1.1 General Data

The mask 1.1 *General Data* opens automatically after the start of RF-DYNAM 2007.

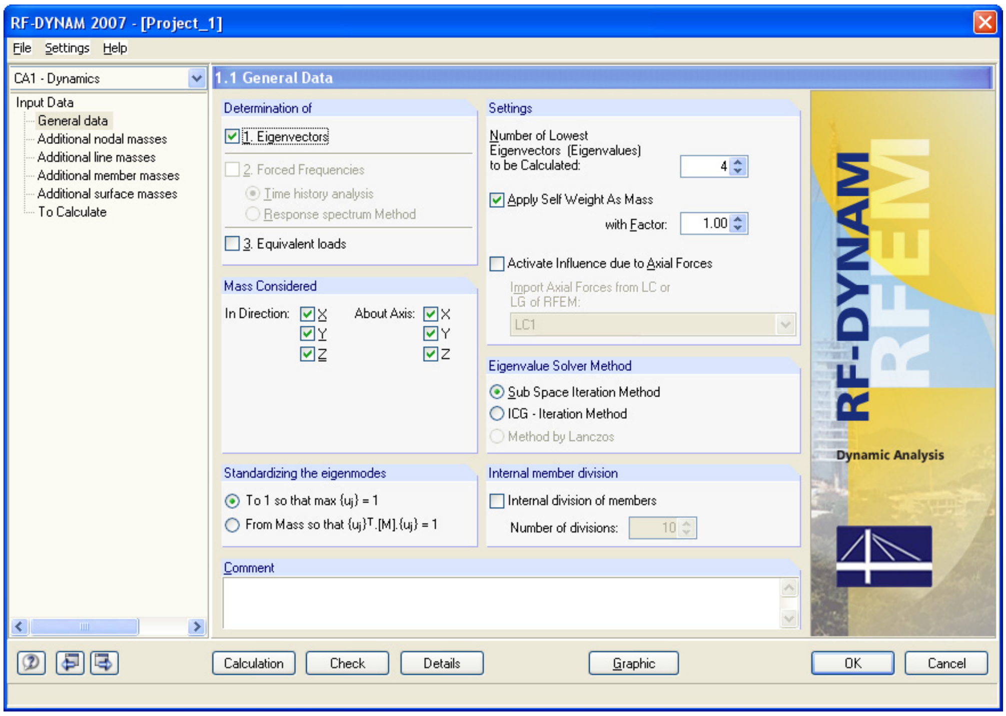
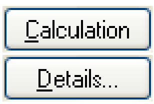


Figure 3.2: Mask 1.1 *General Data*

At first you select here the current dynamic case (if available) in the list above the navigator.



You can also *Comment* the current dynamic case. Before the calculation starts by clicking on the [Calculation] button you have the option to open by means of the [Details] button the dialog where certain calculation parameters can be set.

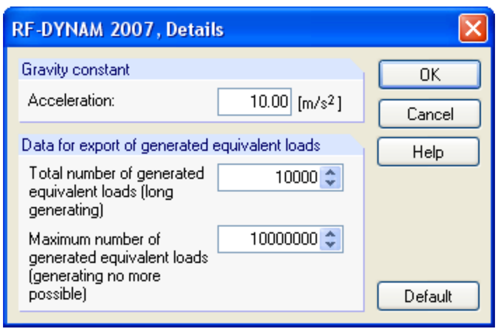


Figure 3.3: Dialog *RF-DYNAM 2007, Details*

Determination of

In this section you can select one of the acquired modules: **RF-DYNAM Basic** (= *Eigenvectors)* or **RF-DYNAM Addition II** (= *Equivalent Loads)*. The modules, whose licence you do not own and are unavailable, are marked by gray letters.

Equivalent loads

This option can be fully utilized only in case if you have the licence for the **RF-DYNAM ADDITION II** module. Then you can enter the values according to the corresponding standards (DIN 4149, EC 8 or IBC 2000) for the calculation of equivalent static loads in the mask 1.7. If you have only RF-DYNAM 2007 BASIC available, this module part will run only as a demoversion.

Settings

RF-DYNAM 2007 calculates the lowest eigenvectors of the structure. The calculation theory generally does not allow the possibility to omit lower eigenvectors and simultaneously calculate greater eigenvectors during the design. In the entry box *Number of Lowest Eigenvectors (Eigenvalues) to be Calculated you* can determine how many eigenvalues RF-DYNAM 2007 should calculate. It is possible to calculate up to 1,000 lowest eigenvectors of a structure.

Apply Self-Weight As Mass

Following data on members, surfaces and bodies of a given structure that were entered in the main program RFEM, the RF-DYNAM module can calculate the structure mass. The factor by which the given mass will be multiplied is set in this entry box. This factor is independent on the load case Self-Weight, which could be possibly defined in RFEM. If you enter *zero* in this box, the weight from RFEM structure data will not be taken into account during the dynamic design.

Activate Influence due to Axial Forces

If you want the geometric rigidity matrix to be included in the calculation, the second order theory will be applied. When the structure is deflected, axial forces induce additional bending moments that can contribute to the increase or decrease of the structure rigidity. Influence of axial forces can be activated in the entry box *Activate Influence due to Axial Forces.*

You select in the list a certain load case or load group from which you want to import normal stresses. Tension stresses lead to the natural frequency increase.

Mass Considered

In this section you determine in which global spatial directions the mass will be regarded. The RF-DYNAM 2007 module takes into account not only the mass of members, surfaces and bodies, but also the mass entered in the masks 1.2 *Additional Nodal Masses,* 1.4 *Additional Member Masses* and 1.5 *Additional Surface Masses*.

Eigenvalue Solver Method

The selection of the eigenvalue calculation method has decisive influence on calculation time during the dynamic design. RF-DYNAM 2007 simultaneously offers different calculation procedures to obtain structure eigenvalues.

The subspace iteration method is suitable for small and medium cases for which a large number of eigenvalues should be calculated. All eigenvalues are simultaneously calculated in one step, which is demanding for an operational memory.

The method of combined gradients (ICG method) was developed for extensive cases when the computer operational memory is insufficient. Eigenvalues are calculated consecutively in this case. Hence, this method is suitable for big models for which only a smaller number of eigenvalues should be evaluated.

Standardizing the eigenmodes

The eigenmodes can be standardized for the calculation of mode masses according to the displacement $\{u_j\}$ or the contributions $\{u_j\}^T$ [M] $\{u_j\}$.

Internal member division

For the better approximation analysis it can be necessary under certain conditions to enter a greater number of member divisions. Hence, an accuracy of a member representation is increased which is suitable mainly for tapered members or members with an elastic foundation. If you enter the value higher than 1, the program separates the member internally. It is necessary to enter integers in this box.

<u>Example:</u> In case of the spatially defined cantilever beam with the entered value *1* for the member division you can at most calculate six lowest natural frequencies. For the simple member division after entering the value *2* inthe corresponding entry box you can calculate 12 lowest natural frequencies. If you want to achieve the same by the equivalent structure entry in RFEM, the beam would have to be divided by one node.

Comment

The user can record his own comments in this field.

3.3.2 Mask 1.2 Additional Nodal Masses

RF-DYNAM imports the structure entered in the main program RFEM. If you have entered in the mask 1.1 *General Data* in the box *Apply Self Weight As Mass a*factor higher than zero, then RF-DYNAM takes for the basis of the eigenvalue analysis the self weight of structure objects as the weighted mass. The mass can be defined additionally or alternatively in the masks 1.2 - 1.5.

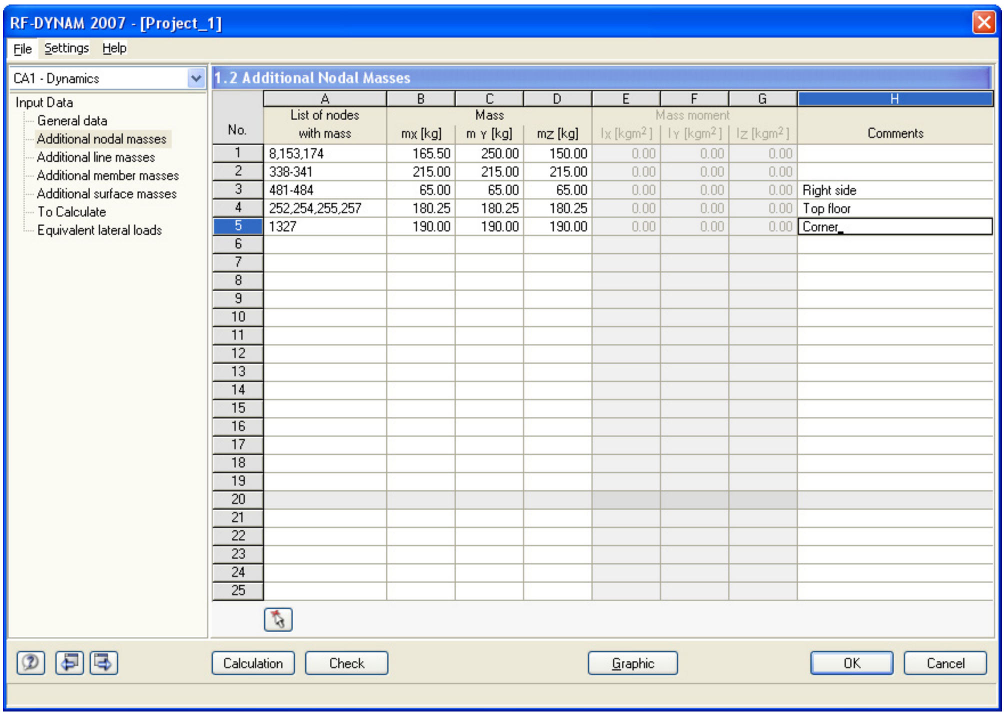


Figure 3.4: Mask 1.2 *Additional Nodal Masses*

You can easily import to the module the loads from RFEM by using the button [Import Nodal Loads of Load Case from RFEM and Set as Mass...]. However, only loads defined in the direction of the z axis are imported. In the dialog that opens you can select the original load case. Further in this dialog you can choose the factor by which the imported masses will be multiplied (see the following picture).

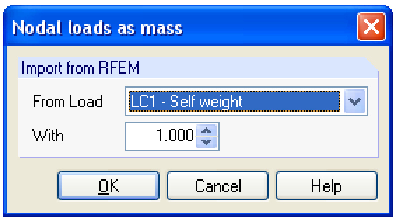


Figure 3.5: Dialog for Choosing Load Case and Factor for Additional Masses

If only individual loads on nodes in RF-DYNAM should be defined, you can use the function [Pick Nodes] or you can enter them manually.

List of nodes with mass

Node numbers to which the additional mass shall be assigned

Mass

Amount of mass that shall be assigned to the node

Mass moments

The mass moments that act on the nodes

3.3.3 Mask 1.3 Additional Line Masses

Regarding the fact that the appearance and control of the masks 1.2 - 1.5 are very similar, we mention them only briefly. The functions described in the previous chapter are more or less common for all masks for entering the additional masses.

You can enter the additional line masses in the mask 1.3.

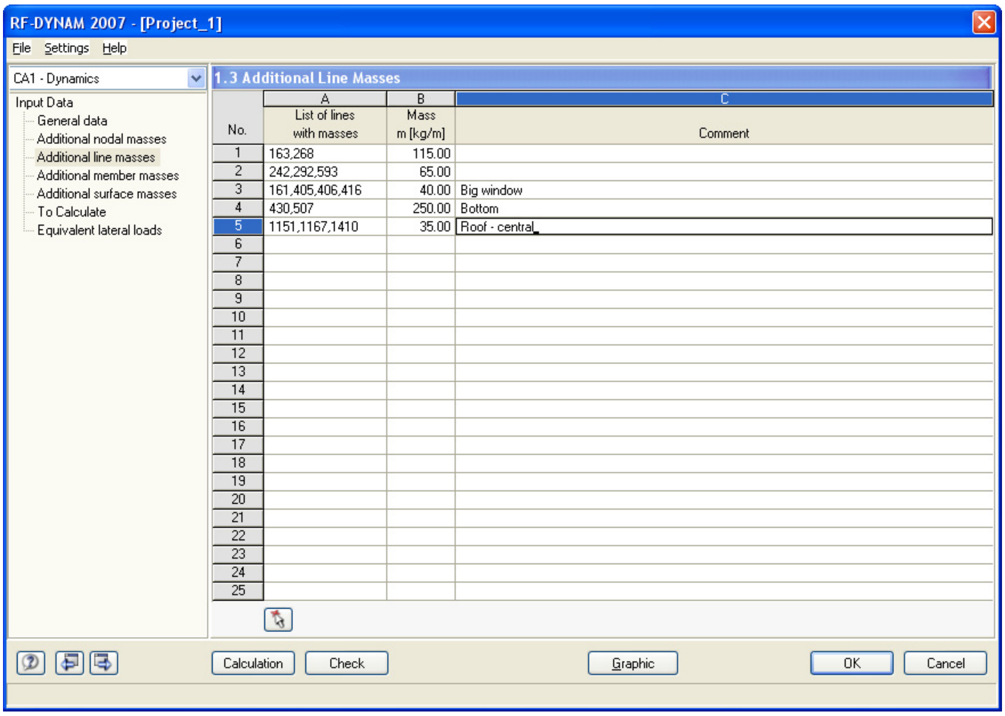


Figure 3.6: Mask 1.3 *Additional Line Masses*

3.3.4 Mask 1.4 Additional Member Masses

You can enter the additional member masses in the mask 1.4. If you import the member loads that were defined as single or trapezoidal ones, then they will be distributed evenly along the whole member length. It means that if a nodal load of 10 kN has been defined on a member 5 m long, the load will be converted to a member mass of 200 kg/m.

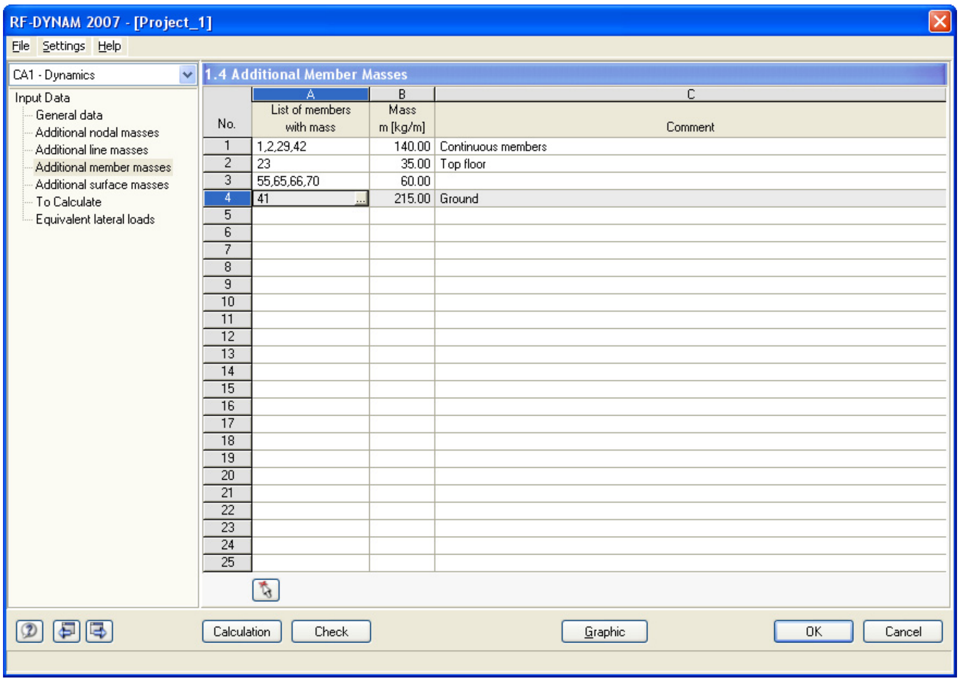


Figure 3.7: Mask 1.4 *Additional Member Masses*

3.3.5 Mask 1.5 Additional Surface Masses

You can define the additional surface masses in the mask 1.5. Also here the possible linear diagrams of surface loads are recalculated to constant surface masses.

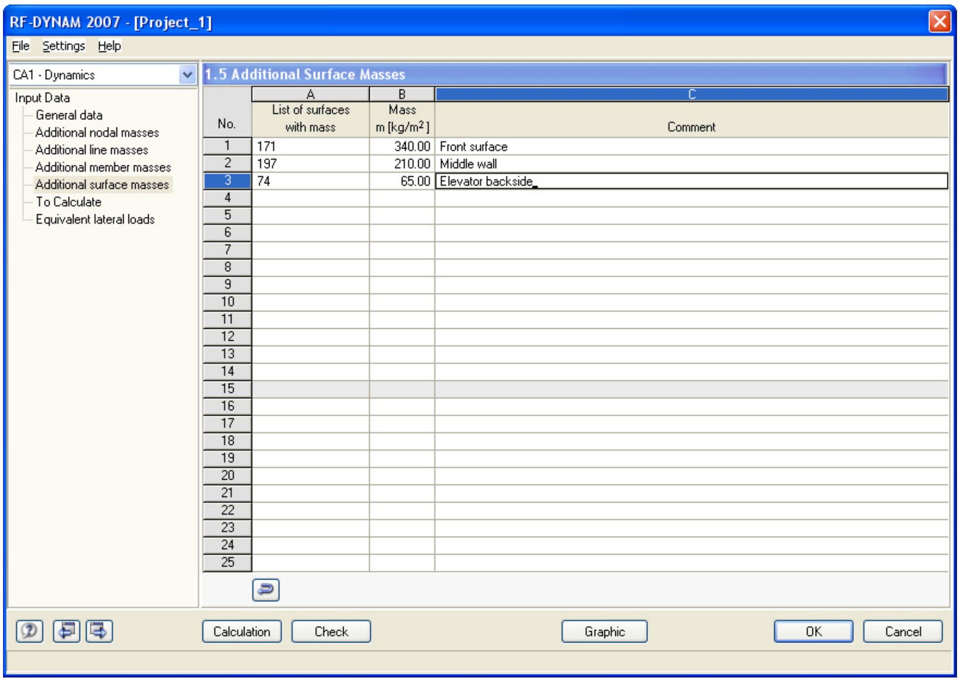


Figure 3.8: Mask 1.5 *Additional Surface Masses*

3.3.6 Mask 1.6 To Calculate for Eigenvibration

In the mask 1.6 *To calculate for eigenvibration* you can select other results that you want to calculate and display. The following options are available: eigenvectors in FE-mesh nodes, masses in FE-mesh nodes and equivalent mass factors.

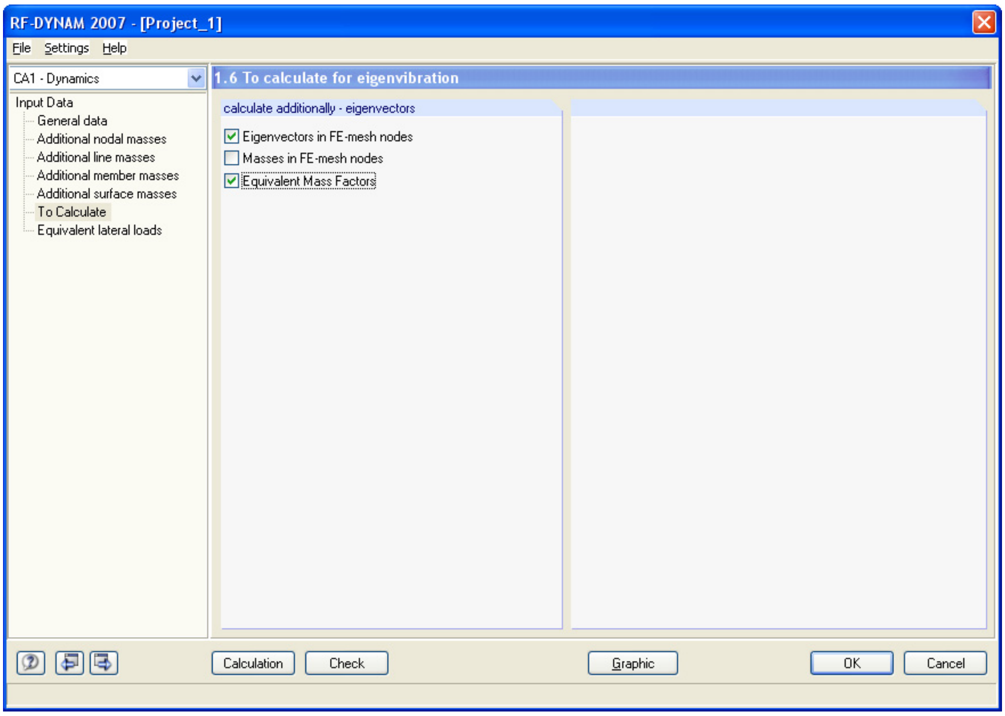


Figure 3.9: Mask 1.6 *To Calculate for Eigenvibration*

Eigenvectors in FE-mesh nodes

If you choose this option, the mask 2.5 is displayed additionally after the calculation. The displacement of eigenmodes, contrary to the results in the masks 2.2 - 2.4, is displayed in all nodes of the FE-mesh.

Masses in FE-mesh nodes

RF-DYNAM 2007 assigns the total structure mass to the individual nodes of the FE-mesh. However, only active masses (the masses that influence the dynamic behaviour of the structure) are taken into account during the calculation. The result masses in the FE-mesh nodes are shown in the mask 2.6.

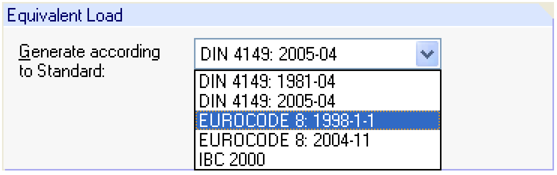
Equivalent Mass Factors

If you choose this option, the equivalent masses and factors of equivalent masses in the directions X, Y and Z are displayed in the output mask 2.7. The details can be found in chapters 3.4 and 4.

3.4 Mask 1.9 Equivalent Loads

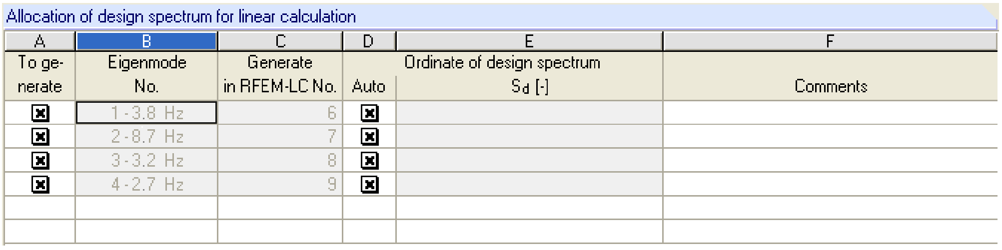
It is only possible to open this mask if you have the licence for the RF-DYNAM ADDITION II module.

Equivalent Loads



From the selection list *Generate according to Standard you* have access to the dialog below where you can enter input parameters after standards **DIN 4149: 1981-04, DIN 4149: 2005-04**, **EUROCODE 8: 1998-1-1, EUROCODE 8: 2004-11** or **IBC 2000**.

Selection of Eigenmodes



Allocation of design spectrum for linear calculation

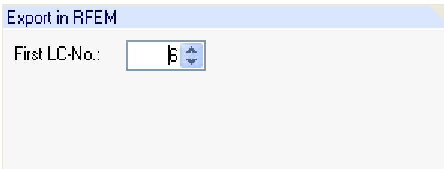
A	B	C	D	E	F
To generate	Eigenmode No.	Generate in RFEM-LC No.	Auto	Ordinate of design spectrum S_d [-]	Comments
☒	1 - 3.8 Hz	6	☒		
☒	2 - 8.7 Hz	7	☒		
☒	3 - 3.2 Hz	8	☒		
☒	4 - 2.7 Hz	9	☒		

To generate and Eigenmode No.

You can specify in these two columns which natural frequencies calculated in the RF-DYNAM BASIC module shall be considered for the calculation of equivalent loads.

Generate in RFEM – LC No.

In this column the number of the RFEM load case is displayed into which the generated equivalent loads will be imported. The direction of load action always corresponds to the direction of the eigenvector. The number of the first RFEM load case can be set during the export to RFEM.



Auto

If you tick this check box, the factors S_d, resp. S_{dH} and S_{dV} of the design spectrum are calculated automatically. It is also possible to enter these values manually; then the equivalent loads can be calculated even on the basis of input values that do not correspond to the given standard.

Ordinate of design spectrum

This value is defined as the function of the T structure eigenperiod.

Comments

For each generated load case a comment can be entered.

Standard Parameters DIN 4149: 1981-04

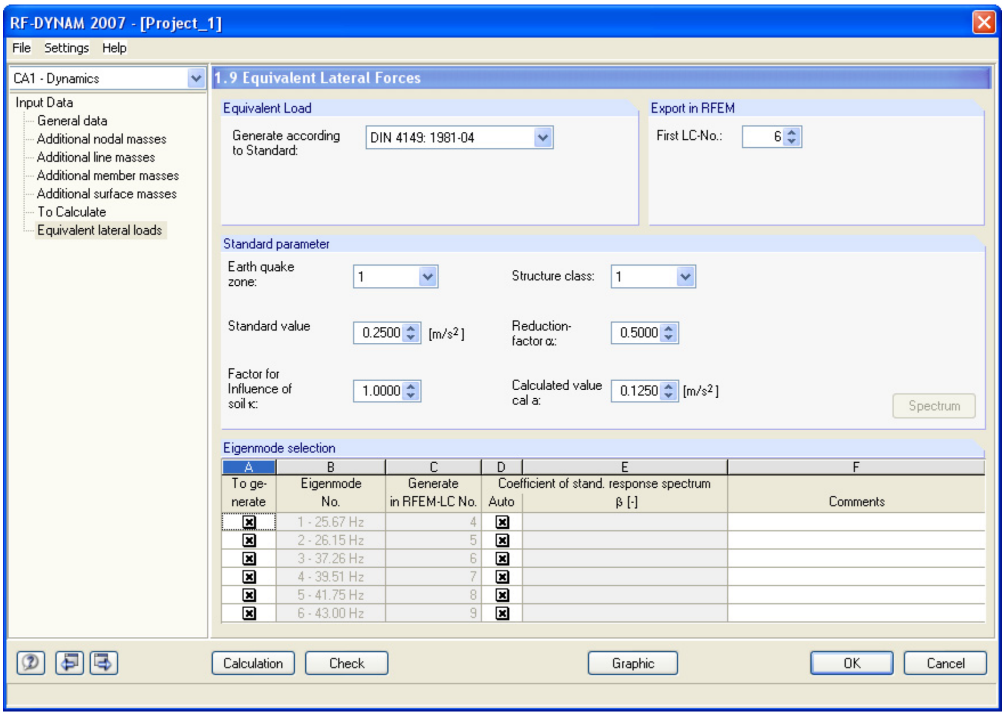


Figure 3.10: Mask 1.9 *Equivalent Lateral Loads* after DIN 4149: 1981-04

Earth quake zone

We distinguish different seismic zones on the earth surface depending on the structure of the earth crust and the position of tectonic layers. The seismic zone is characterized by the value a_0 which corresponds to the estimated acceleration.

Standard value a_0

The program automatically substitutes the design acceleration value depending on the seismic zone if you have specified the seismic zone 1 - 4.

Factor for Influence of soil κ

This factor has in extreme cases either the value 1.0 (hard soil) or 1.4 (loose soil).

Structure class

The site class indicates the level of the construction protection and the social importance of the building. Objects are divided into 3 categories that are specified in the standard. In Central Europe, it is in principle sufficient to consider the object classes 1 - 4. Obviously, the user can also enter the different object class according to other standards and seismic zones, but he himself must supply valid acceleration values then.

Reduction factor α

The design acceleration values a_0 can be multiplied by the reduction factor α depending on the object class and the seismic zone. For further information see DIN 4149, chapter 7.2.3.

Calculated value cal a

This value depends on the design acceleration value a_0, the reduction factor α and the factor for soil influence κ. The value cal a is calculated automatically after entering these parameters, but can be altered additionally as well.

The button [Spectrum] serves for a graphic display of a given spectrum, based on entered parameters. This button is activated after the successful calculation course of natural frequencies. If you do not tick this box in the *Auto* column, you can alter the factors for spectrum directions.

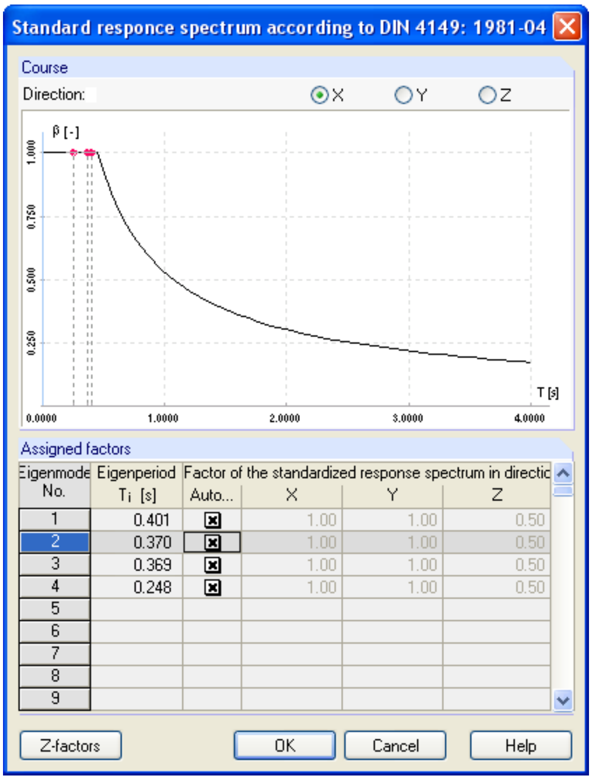


Figure 3.11: Standardized Response Spectrum after DIN 4149: 1981-04

The factors for the Z direction can be determined separately in the table that you open by clicking on the [Z-factors] button. The values for the vertical direction are set by default here in accordance with the standard DIN 4149 and correspond to 50% of the horizontal seismic load component.

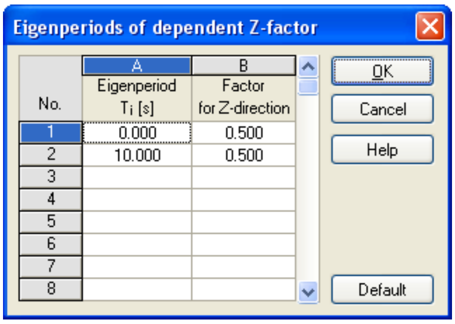


Figure 3.12: Z Factors

Standard Parameters DIN 4149: 2005-04

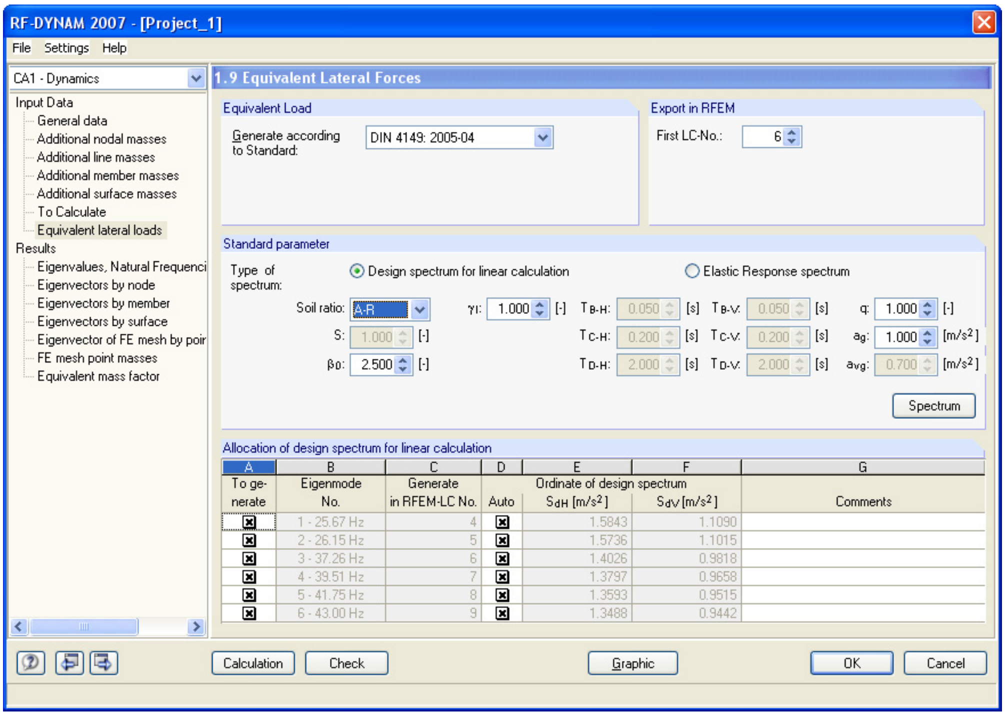


Figure 3.13: Mask 1.9 *Equivalent Loads* after DIN 4149: 2005-04, option *Design Spectrum for Linear Calculation*

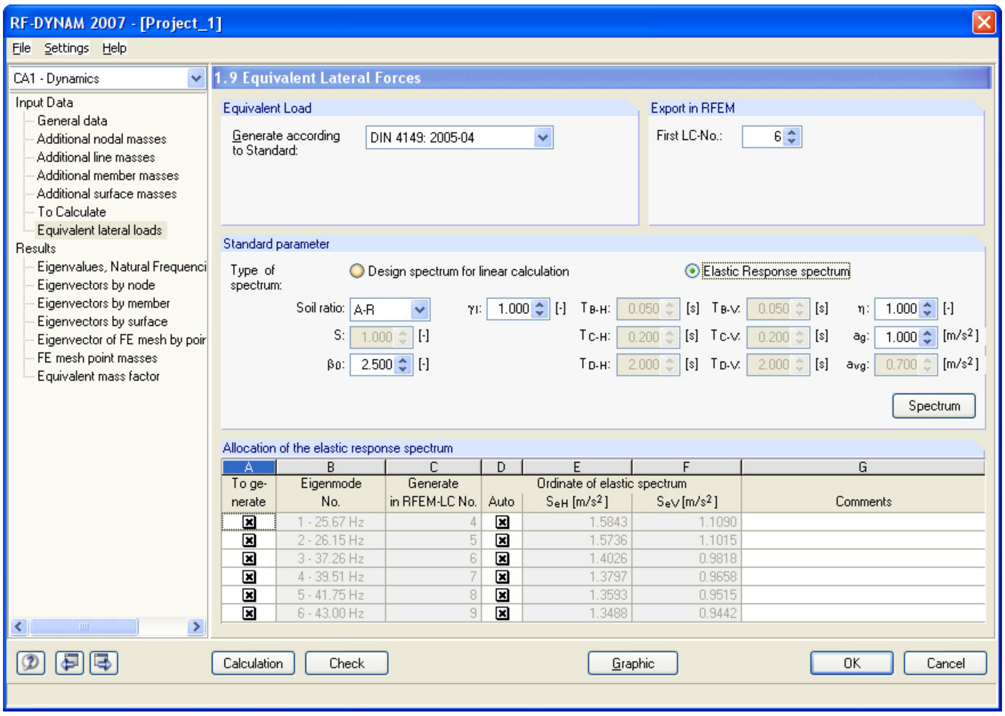


Figure 3.14: Mask 1.9 *Equivalent Loads* after DIN 4149: 2005-04, option *Elastic Response Spectrum*

If the equivalent loads are generated according to DIN 4149: 2005-04, the user will have the option to select either *Design spectrum for linear calculation* or *Elastic Response spectrum.* Individual parameters of the standard DIN 4149: 2005-04 are described below.

Classes of geological soil

R	Regions with a rock soil
T	Transition regions among R and S class regions and further regions of relatively shallow sedimentation basins
S	Regions with deep basins filled with thick sediments

Site classes

A	Non-weathered (parent) rocks with high rigidity Predominant velocity of the shear wave propagation: > 800 m/s
B	Moderately weathered rocks, resp. rocks with low rigidity or gritty (loose) ones, eventually mixed soils with considerable friction with a higher degree of soil density, eventually in rigid consistency (e.g. cohesionless rocks loaded by a glacier) Predominant velocity of the shear wave propagation: 350 m/s - 800 m/s
C	Strongly to fully weathered rocks or gritty (loose) ones, eventually mixed cohesionless soils with medium soil density, eventually at least in rigid consistency or fine-grained (cohesive) soils at least in rigid consistency Predominant velocity of the shear wave propagation: 150 m/s - 350 m/s

For the input values A, B or C and also R, T or S the following input parameters of the design spectrum are given:

Parameter values to express horizontal spectrum

Soil conditions	S	T_B [s]	T_C [s]	T_D [s]
A-R	1.00	0.05	0.20	2.0
B-R	1.25	0.05	0.25	2.0
C-R	1.50	0.05	0.30	2.0
B-T	1.00	0.01	0.30	2.0
C-T	1.25	0.01	0.40	2.0
C-S	0.75	0.01	0.50	2.0

Parameter values to express vertical spectrum

Soil conditions	S	T_B [s]	T_C [s]	T_D [s]
A-R	1.00	0.05	0.20	2.0
B-R	1.25	0.05	0.20	2.0
C-R	1.50	0.05	0.20	2.0
B-T	1.00	0.01	0.20	2.0
C-T	1.25	0.01	0.20	2.0
C-S	0.75	0.01	0.20	2.0

S Soil parameter

T_B, T_C, T_D Control periods of response spectrum

β_0 Spectral acceleration factor with referential value β_0 = 2.5 for 5 % viscous damping

Ductility factor q

The ductility factor *q* varies between 1.50 and 5.00 and is determined by the type of the supporting structure, building ductility, regularity of building elevation and by the type of reinforcing elements failure. It is calculated using the following equation:

$q = q_o * k_R * k_w \geq 1.5$

Correcting damping factor η

The correcting damping factor with respect to the referential value $\eta = 1$ for 5 % viscous damping is calculated as follows:

$$\eta = \sqrt{\frac{10}{(5+\xi)}} \geq 0.55$$

Design ground acceleration a_g

The design ground acceleration depends on the seismic zone and its value can be determined according to the following table and the figure 2 - *Seismic zones of Germany* in DIN 4149: 2005-04.

Seismic zone	Intensity range	Design ground acceleration a_g [m/s²]
0	6.0 ≤ I < 6.5	-
1	6.5 ≤ I <7.0	0.4
2	7.0 ≤ I < 7.5	0.6
3	7.5 ≤ I	0.8

Importance factor γ_I

High-rise buildings are divided into four categories depending on their importance for a public protection:

Importance category	Site objects	Importance factor γ_I
I	A building with small importance for public safety, e.g. agricultural buildings.	0.8
II	Regular buildings that do not fall into other category, e.g. housing buildings.	1.0
III	Buildings whose earthquake resistance is very important regarding consequencies that would arise from their collapse, e.g. extensive housing buildins, office buildings, schools, public places, cultural facilities, department stores etc.	1.2
IV	Buildings whose preservation in case of an earthquake is very important for public protection, e.g. hospitals, important facilities for help during catastrophes and objects of safety units, fire department stations etc.	1.4

The [Spectrum] button serves for a graphic display of a given spectrum based on entered parameters. If you do not tick this box in the *Auto* column, you can alter the factors for spectrum directions.

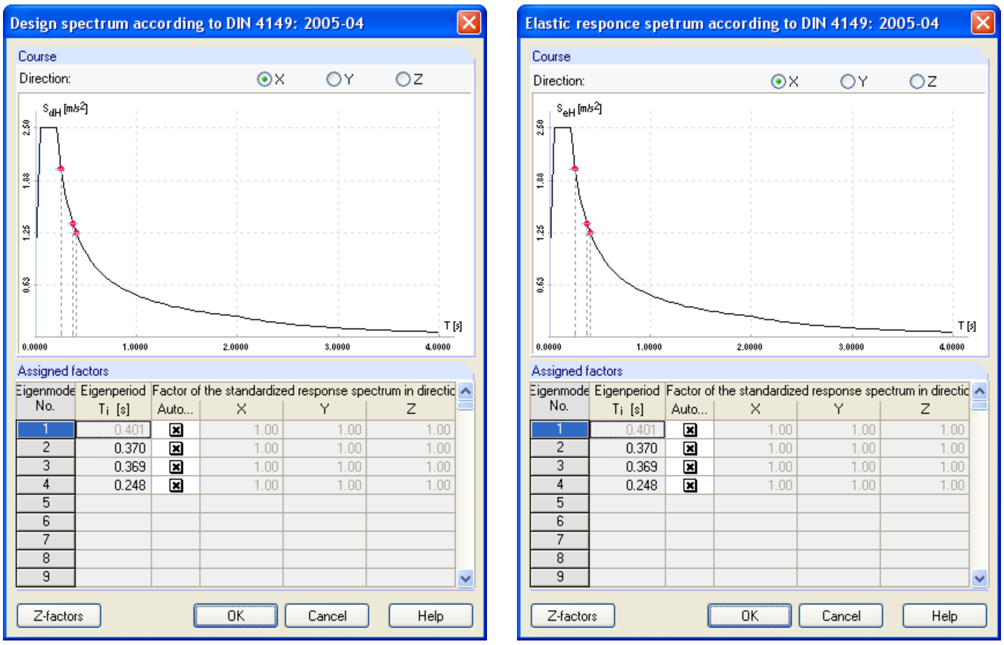


Figure 3.15: Design Spectrum for Linear Calculation   Elastic Response Spectrum

The factors for the Z direction can be determined separately in the table that you open by clicking on the [Z-factors] button. The values for the Z direction are set by default in accordance with the standard DIN 4149: 2005-04:

- for eigenperiods 0.0 s correspond to 100 % of the horizontal seismic load component
- for eigenperiods 10.0 s correspond to 100 % of the horizontal seismic load component

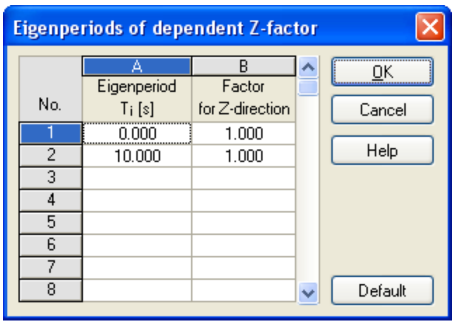


Figure 3.16: Z Factors

Standard Parameters EUROCODE 8: 1998-1-1

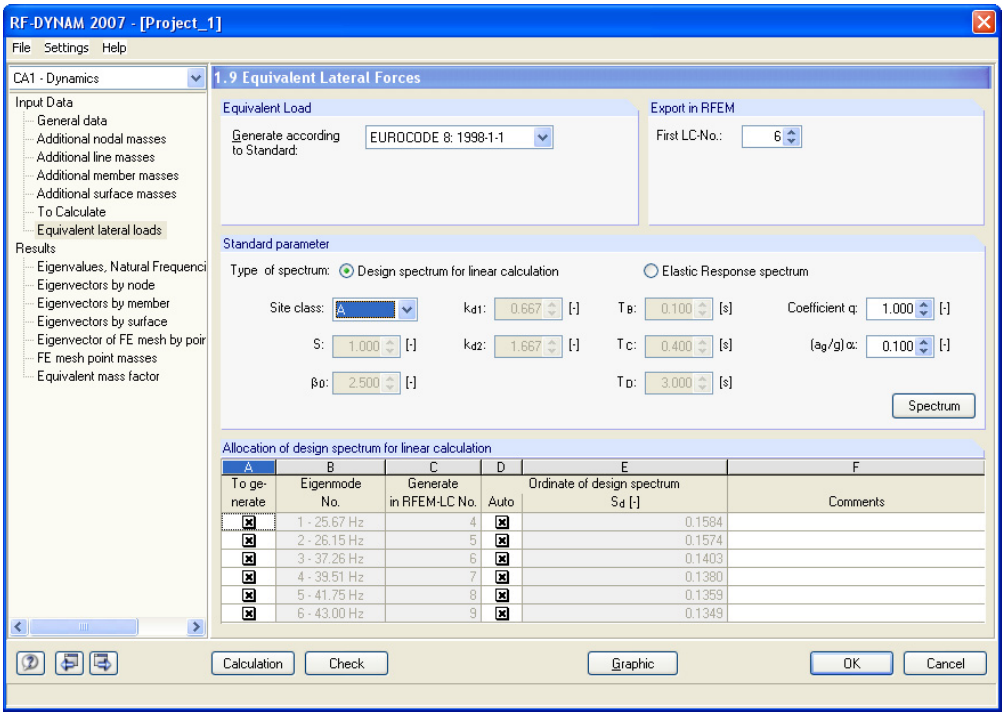


Figure 3.17: Mask 1.9 *Equivalend Loads* acc. to EUROCODE 8: 1998-1-1, option *Design Spectrum for Linear Calculation*

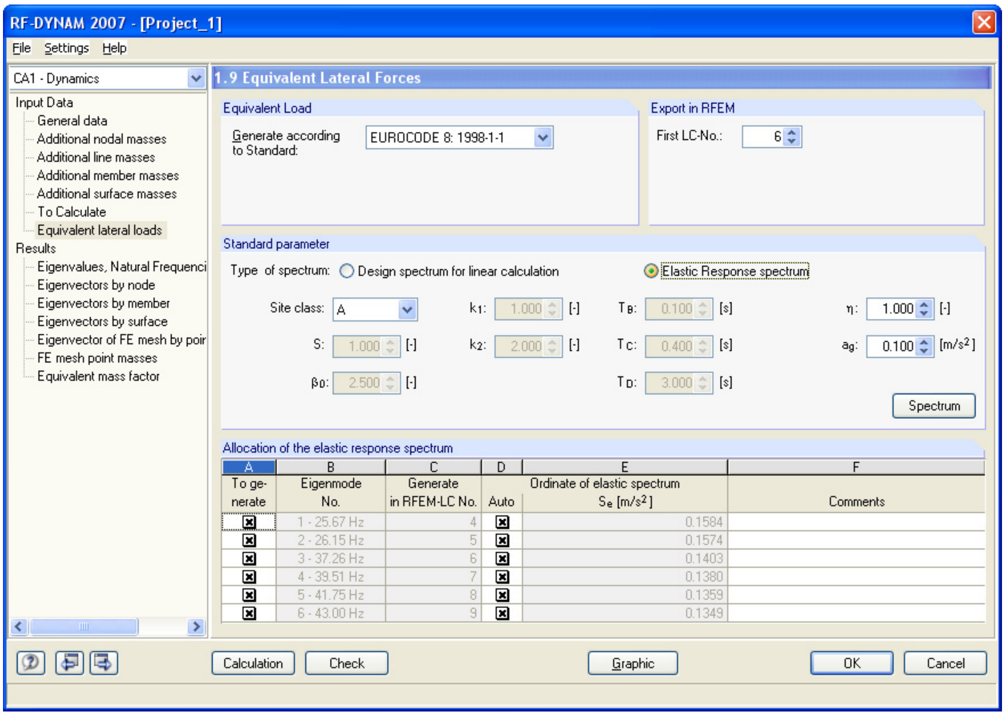


Figure 3.18: Mask 1.9 *Equivalend Loads* according to EUROCODE 8: 1998-1-1, option *Elastic Response Spectrum*

If the equivalent loads are generated according to Eurocode 8: 1998-1-1, the user will have the option to select either *Design spectrum for linear calculation* or *Elastic Response spectrum.* The individual parameters of Eurocode 8: 1998-1-1 are described below.

Site classes

A	A rock site with the velocity of the shear wave propagation at least 800 m/s Dense sands, gravel or over-consolidated clay with the velocity of the shear wave propagation v_s in depth of 10 m at least 400 m/s
B	Moderately dense gravel, sand or rigid clay; v_s at least 200 m/s in depth of 10 m
C	Soils with the v_s lower than 200 m/s in the top 20 m layer

According to the site class A, B or C the following input parameters for the design spectrum are given:

Site class	S	β_o	k_{d1}	k_{d2}	k_1	k_2	T_b [s]	T_c [s]	T_D [s]
A	1.0	2.5	2/3	5/3	1.0	2.0	0.10	0.40	3.0
B	1.0	2.5	2/3	5/3	1.0	2.0	0.15	0.60	3.0
C	0.9	2.5	2/3	5/3	1.0	2.0	0.20	0.80	3.0

S Site parameter

β_0 Spectral acceleration factor for 5 % viscous damping

k_{d1}, k_{d2} Indices shaping design spectrum for periods greater than T_c resp. T_D

k_1, k_2 Indices shaping design specturm for periods greater than T_c resp. T_D

T_b, T_c Limits of constant spectral acceleration range

T_D Period value above which deflection spectrum is constant

Ductility factor q

The ductility factor *q* varies between 1.50 and 5.00 and is determined by the type of the supporting structure, building ductility, regularity of building elevation and by the type of reinforcing elements failure. It is calculated using the following equation:

$q = q_o * k_D * k_R * k_W$

Correcting damping factor η

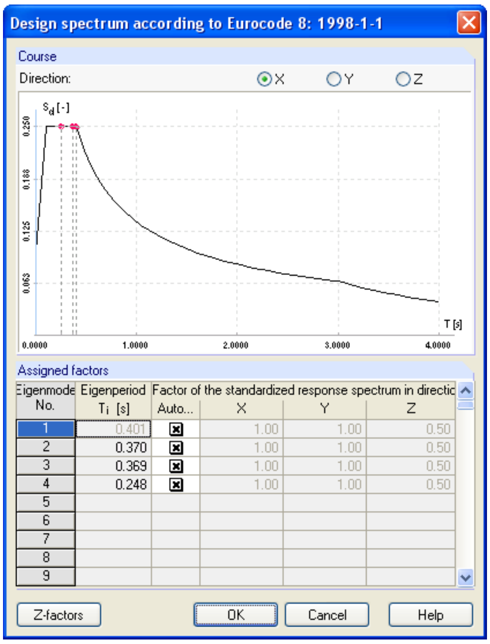
The correcting damping factor with respect to the referential value $\eta = 1$ for 5 % viscous damping is calculated as follows:

$$\eta = \sqrt{\frac{7}{(2+\xi)}} \geq 0.7$$

Acceleration Ratio (a_g / g)

The factor α shows the ratio of the design ground acceleration a_g with the referential repetition period and the gravitational acceleration *g*.

The [Spectrum] button serves for a graphic display of a given spectrum, including entered parameters. If you do not tick this box in the *Auto* column, you can alter the factors for spectrum directions.



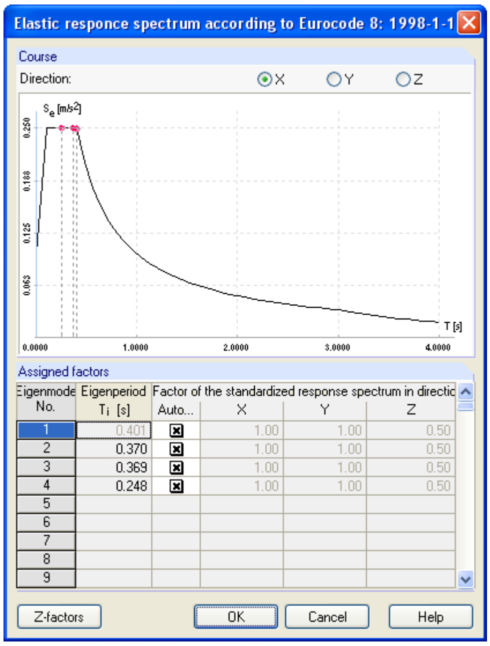


Figure 3.19: Design Spectrum for Linear Calculation Elastic Response Spectrum

The factors for the Z direction can be determined separately in the table that you open by clicking on the [Z-factors] button. The values for the Z direction are set by default in accordance with the standard EC 8:

- for eigenperiods lower than 0.15 s the values are reduced by the factor 0.70
- for eigenperiods greater than 0.5 s the values are reduced by the factor 0.50
- for eigenperiods between 0.15 s and 0.5 s an authomatic linear interpolation runs

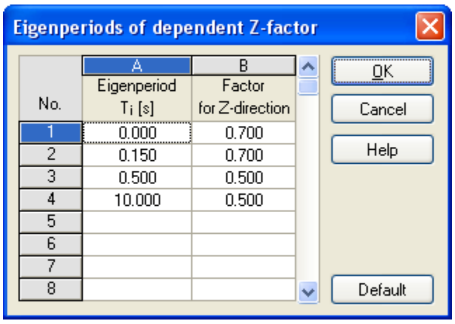


Figure 3.20: Z Factors

Standard Parameters IBC 2000

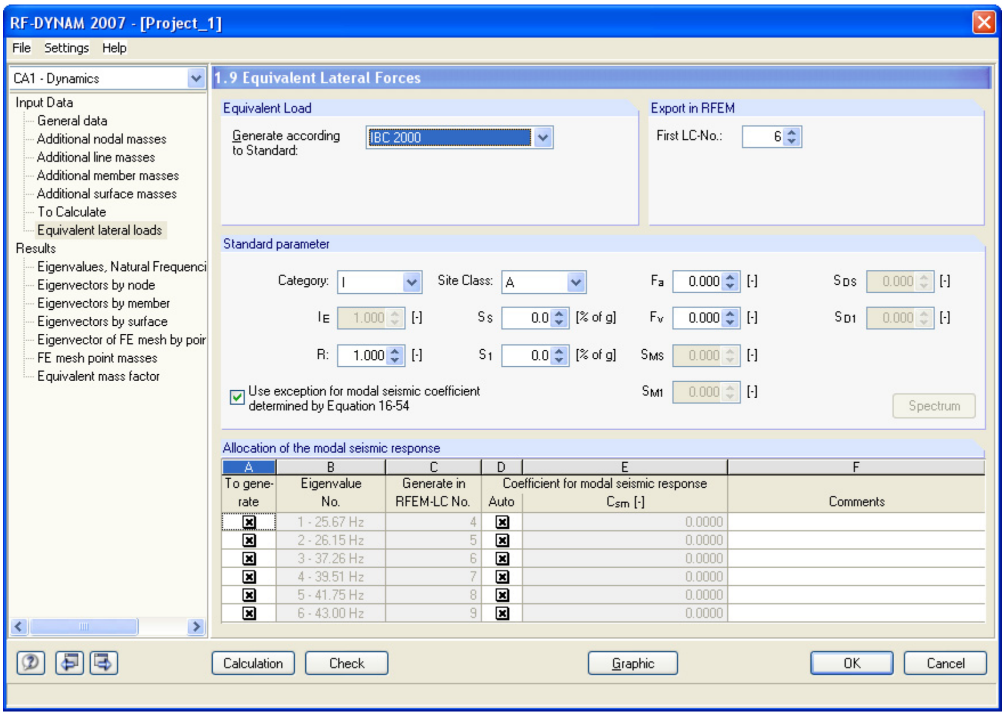


Figure 3.21: Dialog 1.9 *Equivalent Lateral Loads* according to IBC 2000

The [Spectrum] button serves for a graphic display of a given spectrum, including entered parameters. If you do not tick this box in the *Auto* column, you can alter the factors for spectrum directions.

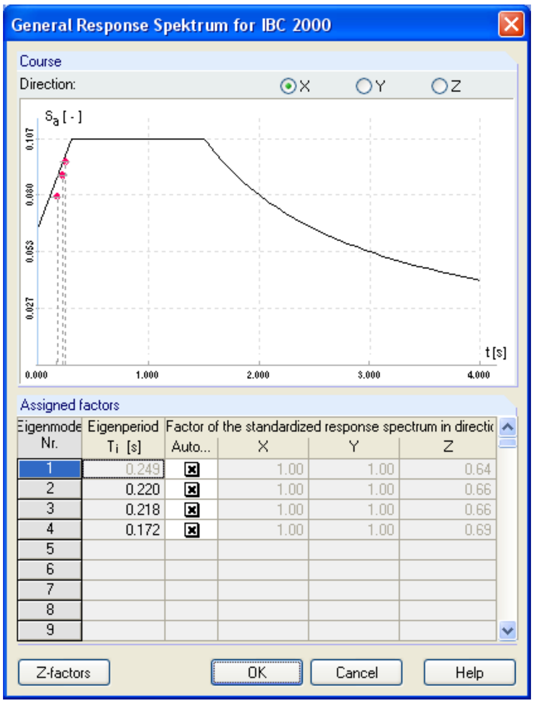


Figure 3.22: General Response Spectrum for IBC

Category

These categories of structures correspond to the Seismic Use Groups stated in the IBC 2000.

1616.2.1 Seismic Use Group I. Seismic Use Group I structures are those not assigned to either Seismic Use Group II or III.

1616.2.2 Seismic Use Group II. Seismic Use Group II structures are those, the failure of which would result in a substantial public hazard due to occupancy or use as indicated by Table 1604.5, or as designated by the building official.

1616.2.3 Seismic Use Group III. Seismic Use Group III structures are those, the failure of which would result in having essential facilities that are required for postearthquake recovery and those containing substantial quantities of hazardous substances, as indicated in Table 1604.5, or as designated by the building official.

Where operational access to a Seismic Use Group III structure is required through an adjacent structure, the adjacent structure shall conform to the requirements for Seismic Use Group III structures. Where operational access is less than 10 feet (3048 mm) from an interior lot line or less than 10 feet (3048 mm) from another structure, access protection from potential falling debris shall be provided by the owner of the Seismic Use Group III structure.

Occupancy Importance Factor I_E

TABLE 1604.5
CLASSIFICATION OF BUILDINGS AND OTHER STRUCTURES FOR IMPORTANCE FACTORS

CATEGORY[a]	NATURE OF OCCUPANCY	SEISMIC FACTOR I_E	SNOW FACTOR I_S	WIND FACTOR I_W
I	Buildings and other structures except those listed in Categories II, III and IV	1.00	1.0	1.00
II	Buildings and other structures that represent a substantial hazard to human life in the event of failure including, but not limited to: • Buildings and other structures where more than 300 people congregate in one area • Buildings and other structures with elementary school, secondary school or day-care facilities with capacity greater than 250 • Buildings and other structures with a capacity greater than 500 for colleges or adult education facilities • Health care facilities with a capacity of 50 or more resident patients but not having surgery or emergency treatment facilities • Jails and detention facilities • Any other occupancy with an occupant load greater than 5,000 • Power-generating stations, water treatment for potable water, waste water treatment facilities and other public utility facilities not included in Category III • Buildings and other structures not included in Category III containing sufficient quantities of toxic or explosive substances to be dangerous to the public if released	1.25	1.1	1.15
III	Buildings and other structures designated as essential facilities including, but not limited to: • Hospitals and other health care facilities having surgery or emergency treatment facilities • Fire, rescue and police stations and emergency vehicle garages • Designated earthquake, hurricane or other emergency shelters • Designated emergency preparedness, communication, and operation centers and other facilities required for emergency response • Power-generating stations and other public utility facilities required as emergency back-up facilities for Category III structures • Structures containing highly toxic materials as defined by Section 307 where the quantity of the material exceeds the exempt amounts of Table 307.7(2) • Aviation control towers, air traffic control centers and emergency aircraft hangars • Buildings and other structures having critical national defense functions • Water treatment facilities required to maintain water pressure for fire suppression	1.50	1.2	1.15
IV	Buildings and other structures that represent a low hazard to human life in the event of failure including, but not limited to: • Agricultural facilities • Certain temporary facilities • Minor storage facilities	1.00	0.8	0.87[b]

a. "Category" is equivalent to "Seismic Use Group" for the purposes of Section 1616.2.
b. In hurricane-prone regions with V>100 miles per hour, I_W shall be 0.77.

Site Class

TABLE 1615.1.1
SITE CLASS DEFINITIONS

SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, AS PER SECTION 1615.1.5		
		Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5{,}000$	Not applicable	Not applicable
B	Rock	$2{,}500 < \bar{v}_s \le 5{,}000$	Not applicable	Not applicable
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \le 2{,}500$	$\bar{N} > 50$	$\bar{s}_u \ge 2{,}000$
D	Stiff soil profile	$600 \le \bar{v}_s \le 1{,}200$	$15 \le \bar{N} \le 50$	$1{,}000 \le \bar{s}_u \le 2{,}000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1{,}000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$; 2. Moisture content $w \ge 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ ft)		

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m², 1 pound per square foot = 0.0479 kPa.

$\mathbf{S_{MS}} = F_a * S_S$

$\mathbf{S_{M1}} = F_V * S_1$

$\mathbf{S_{DS}} = 2/3 * S_{MS}$

$\mathbf{S_{D1}} = 2/3 * S_{M1}$

where:

F_a	Site coefficient defined in Table 1615.1.2(1)
F_V	Site coefficient defined in Table 1615.1.2(2)
S_S	Mapped spectral accelerations for short periods as determined in Section 1615.1
S_1	Mapped spectral accelerations for a 1 second period as determined in Section 1615.1
S_{MS}	Maximum considered earthquake spectral response acceleration for short period as determined in Section 1615.1.2
S_{M1}	Maximum considered earthquake spectral response acceleration for 1 second period as determined in Section 1615.1.2
S_{DS}	Design spectral response acceleration at short periods as determined in Section 1615.1.3
S_{D1}	Design spectral response acceleration at 1 second period as determined in Section 1615.1.3

TABLE 1615.1.2(1)
VALUES OF SITE COEFFICIENT F_a AS A FUNCTION OF SITE CLASS AND MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIODS (S_S)[a]

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT SHORT PERIODS				
	$S_S \le 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	Note b
F	Note b	Note b	Note b	Note b	Note b

a. Use straight line interpolation for intermediate values of mapped spectral acceleration at short period, S_S.
b. Site-specific geotechnical investigation and dynamic site response analyses shall be performed to determine appropriate values.

TABLE 1615.1.2(2)
VALUES OF SITE COEFFICIENT F_V AS A FUNCTION OF SITE CLASS AND MAPPED SPECTRAL RESPONSE ACCELERATION AT 1 SECOND PERIOD (S_1)[a]

SITE CLASS	MAPPED SPECTRAL RESPONSE ACCELERATION AT 1 SECOND PERIOD				
	$S_1 \le 0.1$	$S_1 = 0.2$	$S_1 = 0.3$	$S_1 = 0.4$	$S_1 \ge 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	Note b
F	Note b	Note b	Note b	Note b	Note b

a. Use straight line interpolation for intermediate values of mapped spectral acceleration at 1-second period, S_1.
b. Site-specific geotechnical investigation and dynamic site response analyses shall be performed to determine appropriate values.

Seismic Design Category

TABLE 1616.3(1)
SEISMIC DESIGN CATEGORY BASED ON SHORT PERIOD RESPONSE ACCELERATIONS

VALUE OF S_{DS}	SEISMIC USE GROUP I	II	III
$S_{DS} < 0.167g$	A	A	A
$0.167g \le S_{DS} < 0.33g$	B	B	C
$0.33g \le S_{DS} < 0.50g$	C	C	D
$0.50g \le S_{DS}$	D[a]	D[a]	D[a]

TABLE 1616.3(2)
SEISMIC DESIGN CATEGORY BASED ON 1 SECOND PERIOD RESPONSE ACCELERATION

VALUE OF S_{D1}	SEISMIC USE GROUP I	II	III
$S_{D1} < 0.067g$	A	A	A
$0.067g \le S_{D1} < 0.133g$	B	B	C
$0.133g \le S_{D1} < 0.20g$	C	C	D
$0.20g \le S_{D1}$	D[a]	D[a]	D[a]

Response Modification Coefficient R[a]

TABLE 1617.6
DESIGN COEFFICIENTS AND FACTORS FOR BASIC SEISMIC-FORCE-RESISTING SYSTEMS

BASIC SEISMIC-FORCE-RESISTING SYSTEM	DETAILING REFERENCE SECTION	RESPONSE MODIFICATION COEFFICIENT, R[a]	SYSTEM OVER-STRENGTH FACTOR, Ω_0[g]	DEFLECTION AMPLIFICATION FACTOR, C_d[b]	SYSTEM LIMITATIONS AND BUILDING HEIGHT LIMITATIONS (FEET) BY SEISMIC DESIGN CATEGORY[C] AS DETERMINED IN SECTION 1616.3: A or B	C	D[d]	E[e]	F[e]
1. Bearing Wall Systems									
A. Ordinary steel braced frames	(14)[j] 2211	4	2	3½	NL	NL	160	160	160
B. Special reinforced concrete shear walls	1910.2.4	5½	2½	5	NL	NL	160	160	160
C. Ordinary reinforced concrete shear walls	1910.2.3	4½	2½	4	NL	NL	NP	NP	NP
D. Detailed plain concrete shear walls	1910.2.2	2½	2½	2	NL	NP	NP	NP	NP
E. Ordinary plain concrete shear walls	1910.2.1	1½	2½	1½	NL	NP	NP	NP	NP
F. Special reinforced masonry shear walls	2106.1.1.5	5	2½	3½	NL	NL	160	160	100
G. Intermediate reinforced masonry shear walls	2106.1.1.4	3½	2½	2¼	NL	NL	NP	NP	NP
H. Ordinary reinforced masonry shear walls	2106.1.1.2	2½	2½	1¾	NL	160	NP	NP	NP
I. Detailed plain masonry shear walls	2106.1.1.3	2	2½	1¾	NL	NP	NP	NP	NP
J. Ordinary plain masonry shear walls	2106.1.1.1	1½	2½	1¼	NL	NP	NP	NP	NP
K. Light frame walls with shear panels—wood structural panels/sheet steel panels	2306.4.1/ 2211	6	3	4	NL	NL	65	65	65
L. Light frame walls with shear panels—all other materials	2306.4.5	2	2 ½	2	NL	NL	35	NP	NP
2. Building Frame Systems									
A. Steel eccentrically braced frames, moment-resisting, connections at columns away from links	(15)[j]	8	2	4	NL	NL	160	160	100
B. Steel eccentrically braced frames, nonmoment resisting, connections at columns away from links	(15)[j]	7	2	4	NL	NL	160	160	100
C. Special steel concentrically braced frames	(13)[j]	6	2	5	NL	NL	160	160	100
D. Ordinary steel concentrically braced frames	(14)[j]	5	2	4½	NL	NL	160	100	100
E. Special reinforced concrete shear walls	1910.2.4	6	2½	5	NL	NL	160	160	100
F. Ordinary reinforced concrete shear walls	1910.2.3	5	2½	4½	NL	NL	NP	NP	NP
G. Detailed plain concrete shear walls	1910.2.2	3	2½	2½	NL	NP	NP	NP	NP
H. Ordinary plain concrete shear walls	1910.2.1	2	2½	2	NP	NP	NP	NP	NP
I. Composite eccentrically braced frames	(14)[k]	8	2	4	NL	NL	160	160	100

(continued)

3.5 Result Masks

3.5.1 Mask 2.1 Eigenvalues, Natural Frequencies and Periods

After the calculation has been carried out successfully in the RF-DYNAM module, the first output mask 2.1 *Eigenvalues, Natural Frequencies and Periods* is displayed:

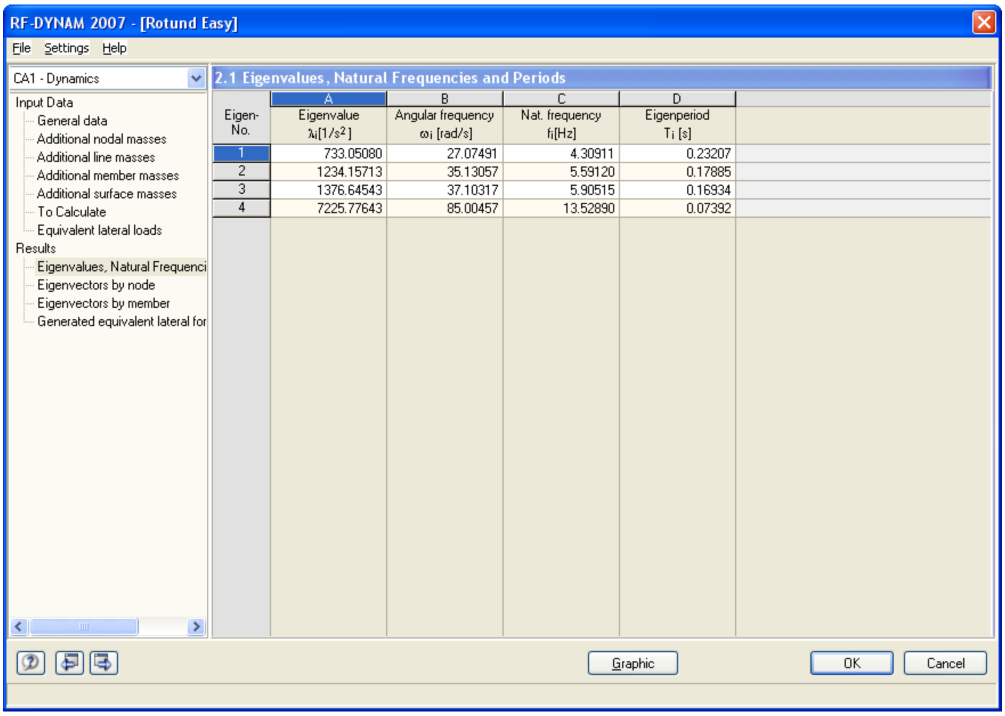


Figure 3.23: Mask 2.1 *Eigenvalues, Natural Frequencies and Periods*

The results are displayed in lines divided according to the natural frequencies into several columns.

Eigenvalue

The eigenvalue λ_i [1/s²] is calculated from the motion equation without dumping. Theoretical principles are described in chapter 5 of this manual.

Angular frequency

The following relation exists between the angular frequency ω_i [rad/s] and the eigenvalue:

$$\lambda_i = \omega_i^2$$

Nat. frequency

The natural frequency f_i [Hz] is the rate of the eigenvector per second. The natural frequency and eigenperiod are in the direct reciprocal relation. The following relation exists between the natural frequency and the angular frequency:

$$\omega_i = 2\pi f_i.$$

Eigenperiod

The eigenperiod T_i [s] shows the time difference necessary for one structural eigenvector. The following relation is applicable:

$$f_i = 1/T_i.$$

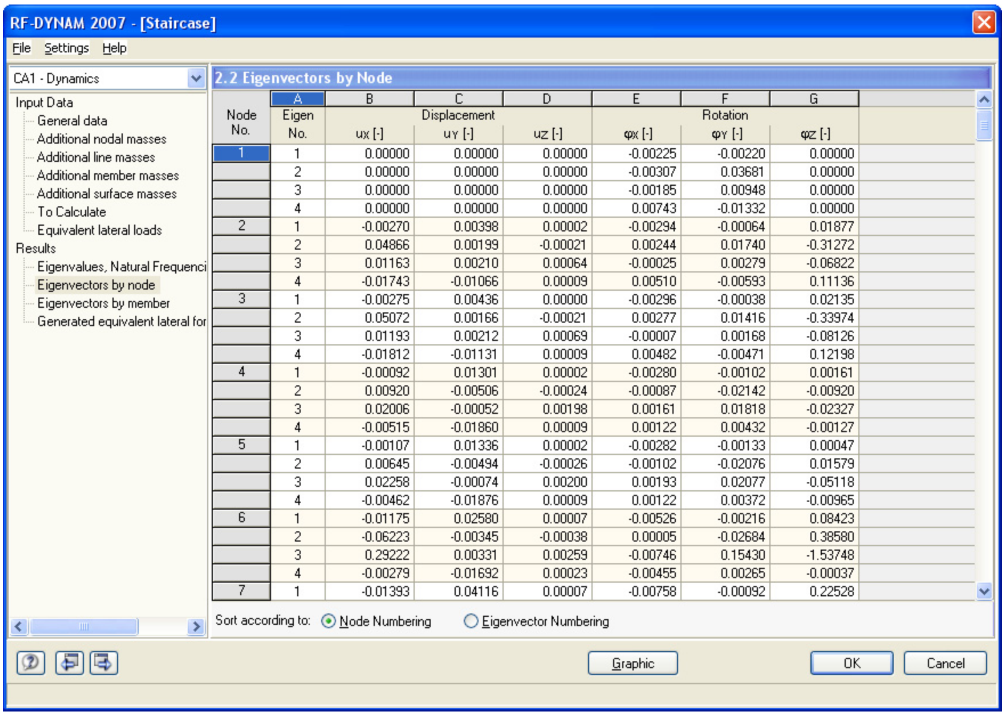
3.5.2 Table 2.2 Eigenvectors by Node

The eigenfunction u(x) exists for every eigenvector. This function represents the shape of the structural eigenvector.

The results are standardized to 1, whereas either the value of the greatest displacement u_i, resp. rotation ϕ_i or the greatest product value of the mass and the second displacement power are considered depending on the setting in the mask 1.1 *General Data.*

Sort according to node/member/surface numbering, eigenvector numbering, FE-mesh nodes or grid nodes: the displacements and node rotations are displayed with regard to a certain object type, sorted in lines according to the node/member/surface numbering, eigenvector numbering, FE-mesh nodes or grid nodes.

The results in the mask 2.2 are sorted according to the nodes.

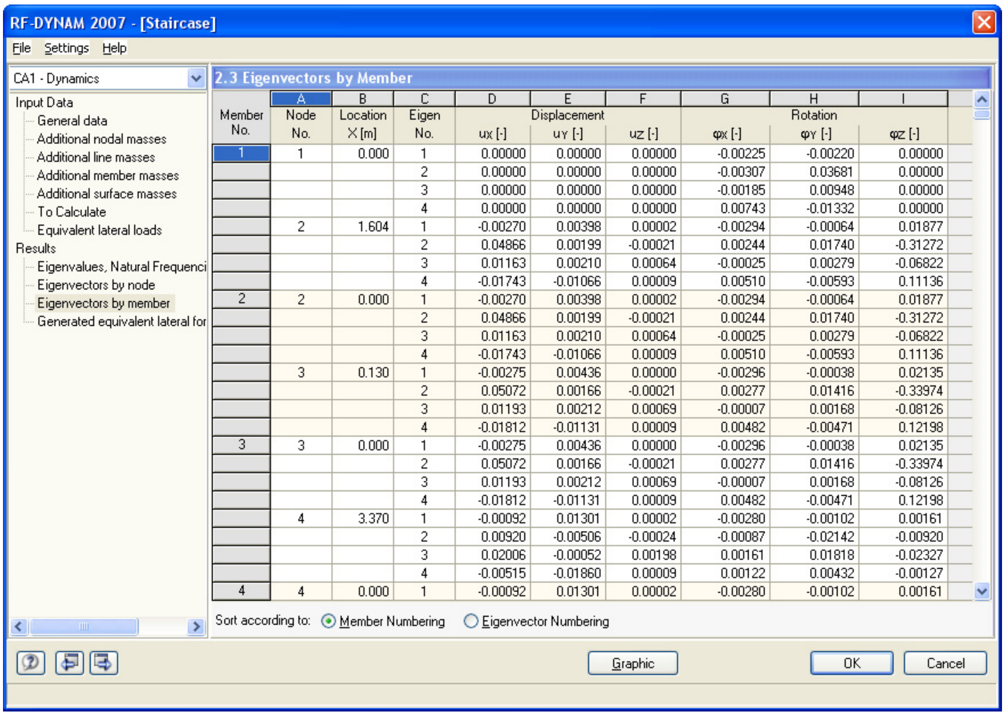


Node No.	A Eigen No.	B Displacement ux [-]	C uY [-]	D uZ [-]	E Rotation φX [-]	F φY [-]	G φZ [-]
1	1	0.00000	0.00000	0.00000	-0.00225	-0.00220	0.00000
	2	0.00000	0.00000	0.00000	-0.00307	0.03681	0.00000
	3	0.00000	0.00000	0.00000	-0.00185	0.00948	0.00000
	4	0.00000	0.00000	0.00000	0.00743	-0.01332	0.00000
2	1	-0.00270	0.00398	0.00002	-0.00294	-0.00064	0.01877
	2	0.04866	0.00199	-0.00021	0.00244	0.01740	-0.31272
	3	0.01163	0.00210	0.00064	-0.00025	0.00279	-0.06822
	4	-0.01743	-0.01066	0.00009	0.00510	-0.00593	0.11136
3	1	-0.00275	0.00436	0.00000	-0.00296	-0.00038	0.02135
	2	0.05072	0.00166	-0.00021	0.00277	0.01416	-0.33974
	3	0.01193	0.00212	0.00069	-0.00007	0.00168	-0.08126
	4	-0.01812	-0.01131	0.00009	0.00482	-0.00471	0.12198
4	1	-0.00092	0.01301	0.00002	-0.00280	-0.00102	0.00161
	2	0.00920	-0.00506	-0.00024	-0.00087	-0.02142	-0.00920
	3	0.02006	-0.00052	0.00198	0.00161	0.01818	-0.02327
	4	-0.00515	-0.01860	0.00009	0.00122	0.00432	-0.00127
5	1	-0.00107	0.01336	0.00002	-0.00282	-0.00133	0.00047
	2	0.00645	-0.00494	-0.00026	-0.00102	-0.02076	0.01579
	3	0.02258	-0.00074	0.00200	0.00193	0.02077	-0.05118
	4	-0.00462	-0.01876	0.00009	0.00122	0.00372	-0.00965
6	1	-0.01175	0.02580	0.00007	-0.00526	-0.00216	0.08423
	2	-0.06223	-0.00345	-0.00038	0.00005	-0.02684	0.38580
	3	0.29222	0.00331	0.00259	-0.00746	0.15430	-1.53748
	4	-0.00279	-0.01692	0.00023	-0.00455	0.00265	-0.00037
7	1	-0.01393	0.04116	0.00007	-0.00758	-0.00092	0.22528

Figure 3.24: Mask 2.2 *Eigenvectors by Node*

3.5.3 Mask 2.3 Eigenvectors by Member

The result eigenvectors in the mask 2.3 are sorted according to the members.

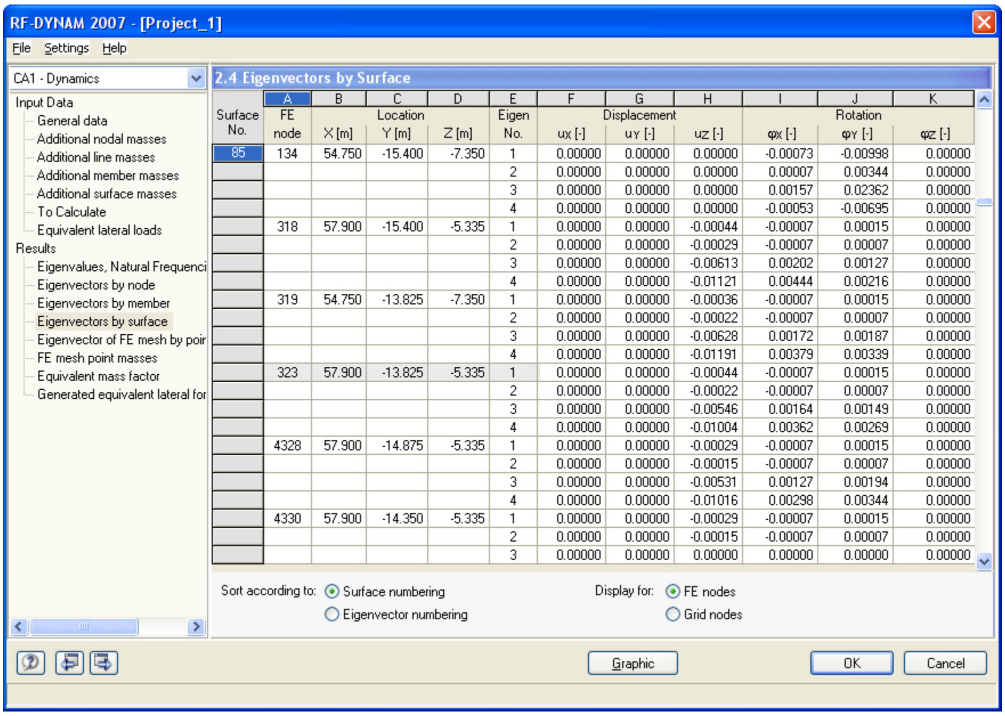


Member No.	A Node No.	B Location X [m]	C Eigen No.	D Displacement ux [-]	E uY [-]	F uZ [-]	G Rotation φX [-]	H φY [-]	I φZ [-]
1	1	0.000	1	0.00000	0.00000	0.00000	-0.00225	-0.00220	0.00000
			2	0.00000	0.00000	0.00000	-0.00307	0.03681	0.00000
			3	0.00000	0.00000	0.00000	-0.00185	0.00948	0.00000
			4	0.00000	0.00000	0.00000	0.00743	-0.01332	0.00000
	2	1.604	1	-0.00270	0.00398	0.00002	-0.00294	-0.00064	0.01877
			2	0.04866	0.00199	-0.00021	0.00244	0.01740	-0.31272
			3	0.01163	0.00210	0.00064	-0.00025	0.00279	-0.06822
			4	-0.01743	-0.01066	0.00009	0.00510	-0.00593	0.11136
2	2	0.000	1	-0.00270	0.00398	0.00002	-0.00294	-0.00064	0.01877
			2	0.04866	0.00199	-0.00021	0.00244	0.01740	-0.31272
			3	0.01163	0.00210	0.00064	-0.00025	0.00279	-0.06822
			4	-0.01743	-0.01066	0.00009	0.00510	-0.00593	0.11136
	3	0.130	1	-0.00275	0.00436	0.00000	-0.00296	-0.00038	0.02135
			2	0.05072	0.00166	-0.00021	0.00277	0.01416	-0.33974
			3	0.01193	0.00212	0.00069	-0.00007	0.00168	-0.08126
			4	-0.01812	-0.01131	0.00009	0.00482	-0.00471	0.12198
3	3	0.000	1	-0.00275	0.00436	0.00000	-0.00296	-0.00038	0.02135
			2	0.05072	0.00166	-0.00021	0.00277	0.01416	-0.33974
			3	0.01193	0.00212	0.00069	-0.00007	0.00168	-0.08126
			4	-0.01812	-0.01131	0.00009	0.00482	-0.00471	0.12198
	4	3.370	1	-0.00092	0.01301	0.00002	-0.00280	-0.00102	0.00161
			2	0.00920	-0.00506	-0.00024	-0.00087	-0.02142	-0.00920
			3	0.02006	-0.00052	0.00198	0.00161	0.01818	-0.02327
			4	-0.00515	-0.01860	0.00009	0.00122	0.00432	-0.00127
4	4	0.000	1	-0.00092	0.01301	0.00002	-0.00280	-0.00102	0.00161

Figure 3.25: Mask 2.3 *Eigenvectors by Node*

3.5.4 Mask 2.4 Eigenvectors by Surface

The result eigenvectors in the mask 2.4 are sorted according to the surfaces.



Surface No.	A FE node	B Location X [m]	C Y [m]	D Z [m]	E Eigen No.	F Displacement ux [-]	G uY [-]	H uZ [-]	I Rotation φX [-]	J φY [-]	K φZ [-]
85	134	54.750	-15.400	-7.350	1	0.00000	0.00000	0.00000	-0.00073	-0.00998	0.00000
					2	0.00000	0.00000	0.00000	0.00007	0.00344	0.00000
					3	0.00000	0.00000	0.00000	0.00157	0.02362	0.00000
					4	0.00000	0.00000	0.00000	-0.00053	-0.00695	0.00000
	318	57.900	-15.400	-5.335	1	0.00000	0.00000	-0.00044	-0.00007	0.00015	0.00000
					2	0.00000	0.00000	-0.00029	-0.00007	0.00007	0.00000
					3	0.00000	0.00000	-0.00613	0.00202	0.00127	0.00000
					4	0.00000	0.00000	-0.01121	0.00444	0.00216	0.00000
	319	54.750	-13.825	-7.350	1	0.00000	0.00000	-0.00036	-0.00007	0.00015	0.00000
					2	0.00000	0.00000	-0.00022	-0.00007	0.00007	0.00000
					3	0.00000	0.00000	-0.00628	0.00172	0.00187	0.00000
					4	0.00000	0.00000	-0.01191	0.00379	0.00339	0.00000
	323	57.900	-13.825	-5.335	1	0.00000	0.00000	-0.00044	-0.00007	0.00015	0.00000
					2	0.00000	0.00000	-0.00022	-0.00007	0.00007	0.00000
					3	0.00000	0.00000	-0.00546	0.00164	0.00149	0.00000
					4	0.00000	0.00000	-0.01004	0.00362	0.00269	0.00000
	4328	57.900	-14.875	-5.335	1	0.00000	0.00000	-0.00029	-0.00007	0.00015	0.00000
					2	0.00000	0.00000	-0.00015	-0.00007	0.00007	0.00000
					3	0.00000	0.00000	-0.00531	0.00127	0.00194	0.00000
					4	0.00000	0.00000	-0.01016	0.00298	0.00344	0.00000
	4330	57.900	-14.350	-5.335	1	0.00000	0.00000	-0.00029	-0.00007	0.00015	0.00000
					2	0.00000	0.00000	-0.00015	-0.00007	0.00007	0.00000
					3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

Figure 3.26: Mask 2.4 *Eigenvectors by Surface*

3.5.5 Mask 2.5 Eigenvectors in FE-Mesh Nodes

The result eigenvectors in the mask 2.5 are displayed according to the FE-mesh nodes. This result table is displayed only in case you have activated the box for the calculation of *Eigenvectors in FE-mesh nodes* in the mask 1.6.

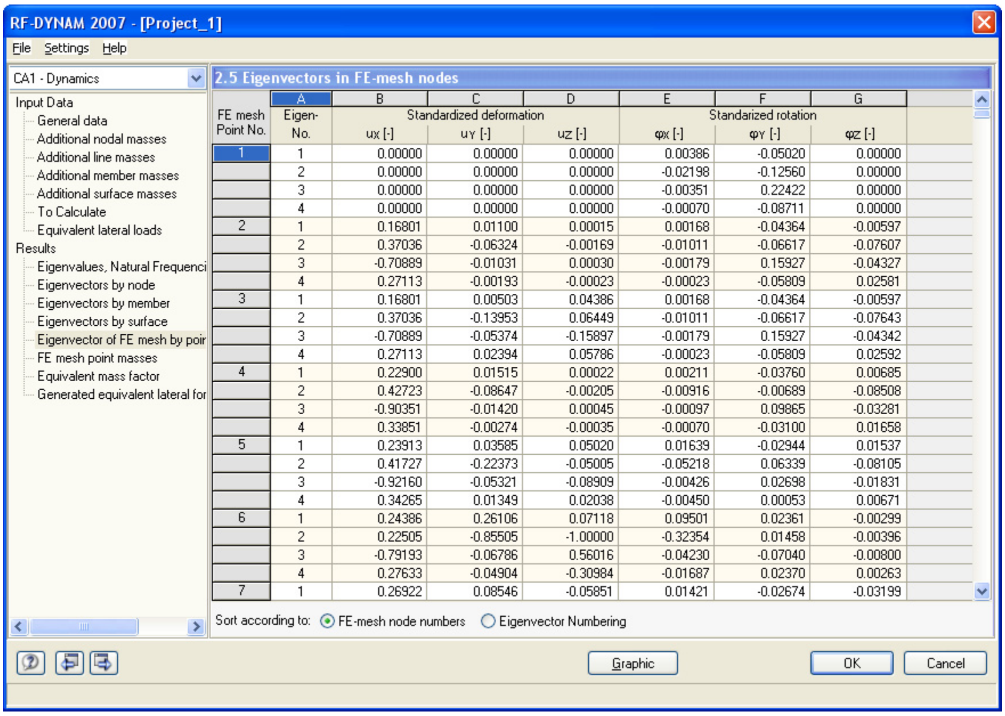


Figure 3.27: Mask 2.5 *Eigenvectors in FE-Mesh Nodes*

3.5.6 Mask 2.6 Masses in FE-Mesh Nodes

This result table is displayed only in case you have activated the box for the calculation of *Masses in FE-mesh nodes* in the mask 1.6.

The masses in the mask are sorted according to FE-mesh node numbers or according to structural objects and are related to a global coordinate system. This coordinate system is already familiar from the structure setting in the main RFEM program. Displayed nodal masses are the relevant ones for a dynamic calculation. It means that e.g. for the node supported in the Y and Z directions only the mass acting dynamically in the direction X is shown. The sum of relevant masses is quoted at the end of the list.

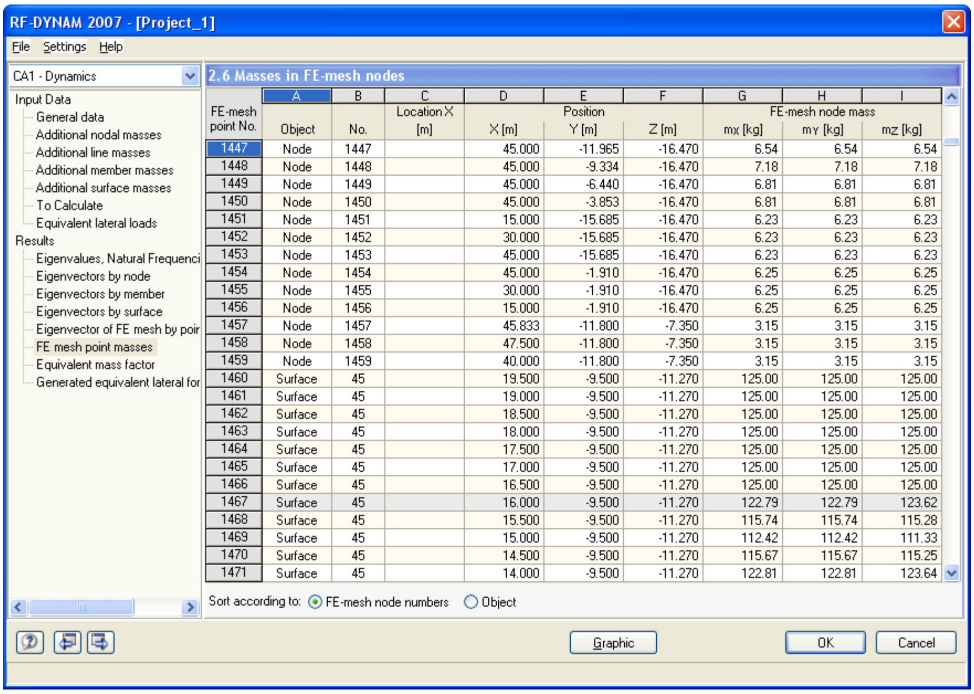


Figure 3.28: Mask 2.6 *Masses in FE-Mesh Nodes*

3.5.7 Mask 2.7 Equivalent Mass Factors

This result table is displayed only in case you have activated the box for the calculation of *Equivalent Mass Factors* in mask 1.6. *Modal mass, Participation factor, Substitute mass and Substitute mass factor* are sorted according to natural frequencies in the table.

The equivalent mass factors can be displayed either separately or in totals using the switch *Sort according to.* By using the second option it is easier to find out e.g. according to EC 8 whether the sum of equivalent masses ("effective modal masses") corresponds at least to 90 % of the total structural mass.

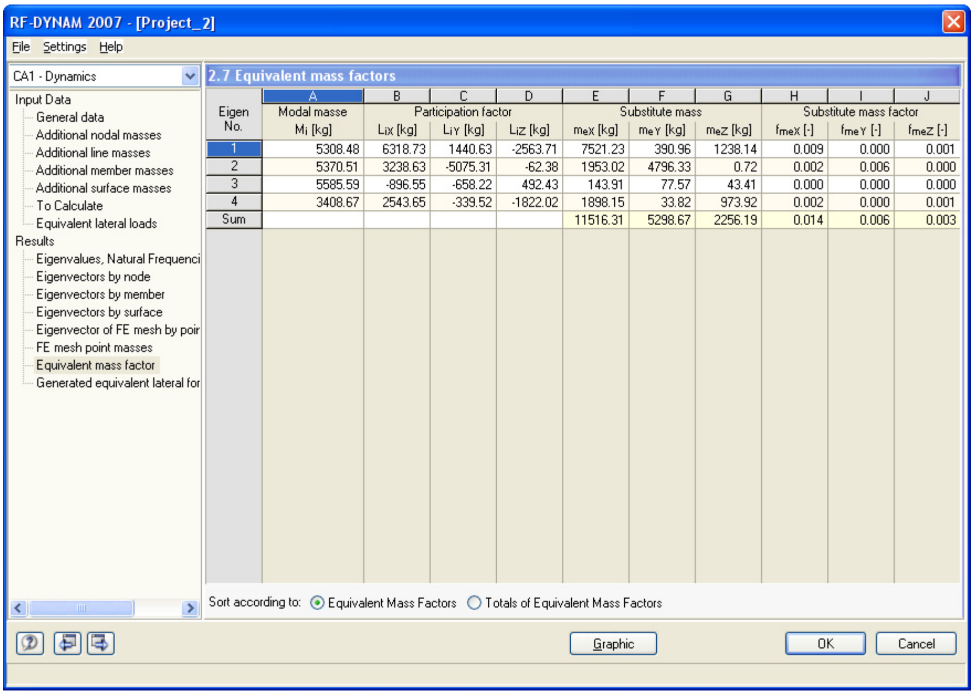
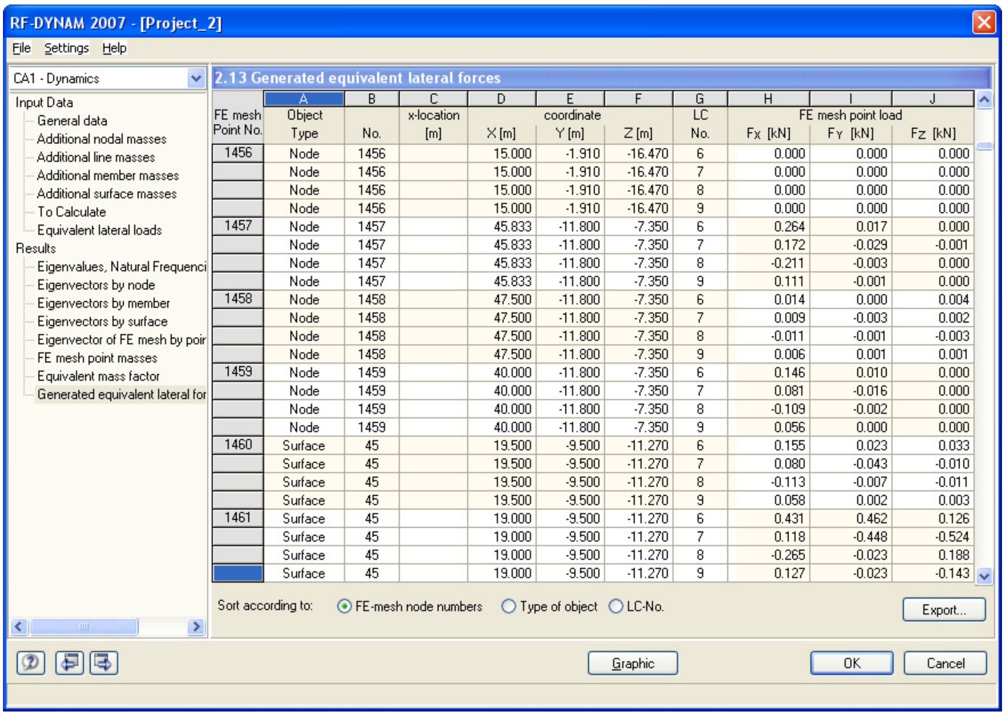


Figure 3.29: Mask 2.7 *Equivalent Mass Factors*

3.5.8 Mask 2.13 Generated Equivalent Lateral Forces

After entering the necessary parameters into the mask 1.9 and selecting the eigenmodes the list of generated equivalent loads is displayed in this mask after the calculation. The result values are nodal loads in a relevant direction.



FE mesh Point No.	A Object Type	B No.	C x-location [m]	D coordinate X [m]	E Y [m]	F Z [m]	G LC No.	H FE mesh point load Fx [kN]	I Fy [kN]	J Fz [kN]
1456	Node	1456		15.000	-1.910	-16.470	6	0.000	0.000	0.000
	Node	1456		15.000	-1.910	-16.470	7	0.000	0.000	0.000
	Node	1456		15.000	-1.910	-16.470	8	0.000	0.000	0.000
	Node	1456		15.000	-1.910	-16.470	9	0.000	0.000	0.000
1457	Node	1457		45.833	-11.800	-7.350	6	0.264	0.017	0.000
	Node	1457		45.833	-11.800	-7.350	7	0.172	-0.029	-0.001
	Node	1457		45.833	-11.800	-7.350	8	-0.211	-0.003	0.000
	Node	1457		45.833	-11.800	-7.350	9	0.111	-0.001	0.000
1458	Node	1458		47.500	-11.800	-7.350	6	0.014	0.000	0.004
	Node	1458		47.500	-11.800	-7.350	7	0.009	-0.003	0.002
	Node	1458		47.500	-11.800	-7.350	8	-0.011	-0.001	-0.003
	Node	1458		47.500	-11.800	-7.350	9	0.006	0.001	0.001
1459	Node	1459		40.000	-11.800	-7.350	6	0.146	0.010	0.000
	Node	1459		40.000	-11.800	-7.350	7	0.081	-0.016	0.000
	Node	1459		40.000	-11.800	-7.350	8	-0.109	-0.002	0.000
	Node	1459		40.000	-11.800	-7.350	9	0.056	0.000	0.000
1460	Surface	45		19.500	-9.500	-11.270	6	0.155	0.023	0.033
	Surface	45		19.500	-9.500	-11.270	7	0.080	-0.043	-0.010
	Surface	45		19.500	-9.500	-11.270	8	-0.113	-0.007	-0.011
	Surface	45		19.500	-9.500	-11.270	9	0.058	0.002	0.003
1461	Surface	45		19.000	-9.500	-11.270	6	0.431	0.462	0.126
	Surface	45		19.000	-9.500	-11.270	7	0.118	-0.448	-0.524
	Surface	45		19.000	-9.500	-11.270	8	-0.265	-0.023	0.188
	Surface	45		19.000	-9.500	-11.270	9	0.127	-0.023	-0.143

Figure 3.30: Mask 2.13 *Generated equivalent lateral forces*

The equivalent loads can be sorted according to the FE-mesh node, the object type or the load case number.

3.5.9 Export of RF-DYNAM Results

You open the following window using the [Export] button in the result mask 2.13 *Generated equivalent lateral forces*.

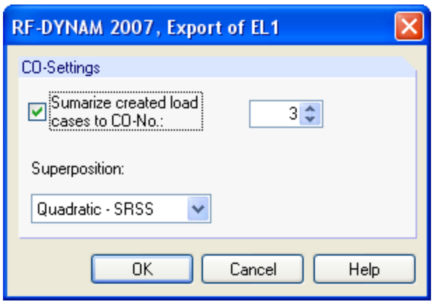


Figure 3.31: Export of Results from RF-DYNAM to RFEM

The modal contributions can be immediately directly superimposed in a given load combination either quadratically (according to the principle of the square root from the square sum SRSS) or linearly. You define the required settings in the section *CO-Settings*.

3.6 Main Menu

The main menu includes all necessary functions to process the RF-DYNAM cases and their results. The items from the main menu can be activated either by clicking on the specific item or by pressing the [Alt] key together with the letter that is quoted in the menu item.

3.6.1 File

[Alt+F]

In this main menu item you find the commands for the creation and modification of the RF-DYNAM cases.

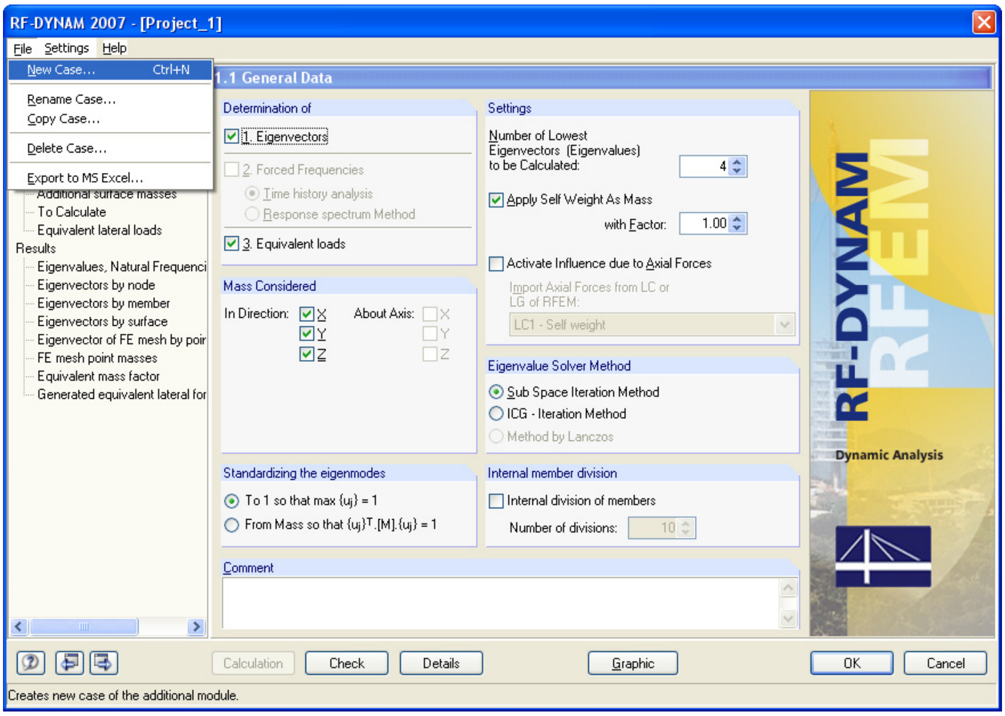


Figure 3.32: Main Menu Item *File*

New Case [Ctrl+N]

This function serves to create the new RF-DYNAM case.

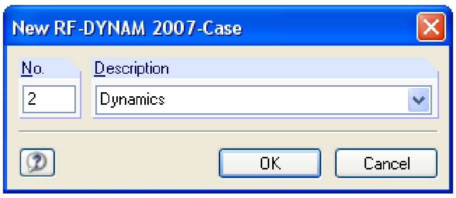
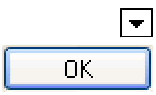


Figure 3.33: Dialog *New RF-DYNAM 2007 Case*



In the opened dialog you enter *No.* and *Description* of the new case. If you click on the [▼] button, the list of all already used descriptions is shown, from which some can be assigned to the new case. The new case is created after clicking on the [OK] button.

Rename Case

This command enables you to change *Description* of the current RF-DYNAM case and optionally to assign other *No.* to the given case. It is necessary to point out that the number already used for a different case can not be selected.

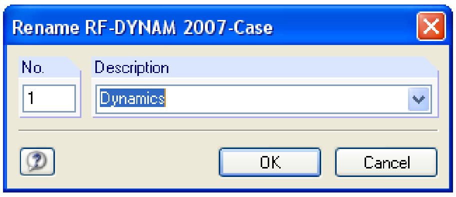


Figure 3.34: Dialog *Rename RF-DYNAM 2007 Case*

Copy Case

This function enables you to copy the already created RF-DYNAM cases.

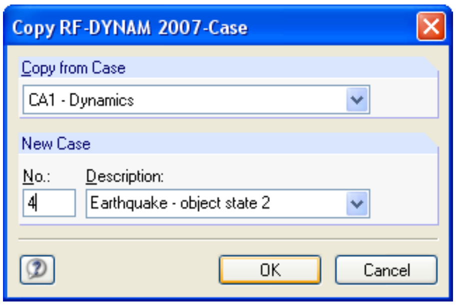


Figure 3.35: Dialog *Copy RF-DYNAM 2007 Case*

Select the RF-DYNAM case that you want to copy from the list after clicking on the button [▼] in the section *Copy from Case*. The description for the new case can also be selected from the list which you open by using the button [▼] in the section *New Case* or you can enter the new name. In case you want to change the new case number that is set automatically, it is necessary to enter the number that has not been assigned to any case so far.

You create the case copy using the [OK] button.

Delete Case

After starting this function from the main menu the list of all RF-DYNAM cases is displayed at first.

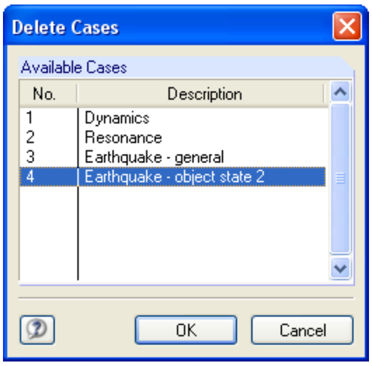


Figure 3.36: Dialog *Delete Cases*

Select the case that you want to delete with the mouse and then delete it by clicking on the [OK] button.

Export to MS Excel

This function serves to export particular or all tables from RF-DYNAM to the MS Excel application.

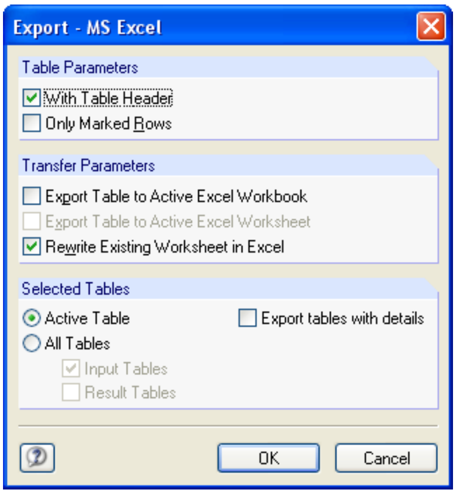


Figure 3.37: Dialog *Export – MS Excel*

3.6.2 Settings

[Alt+S]

The main menu item *Settings* includes the function for the administration of units used in the RF-DYNAM 2007 module.

Units and Decimal Places

After selection of this function the familiar dialog from the main RFEM program is displayed where you can modify the setting of units and decimal places. The RF-DYNAM 2007 module is already set by default in the list of programs and modules on the left.

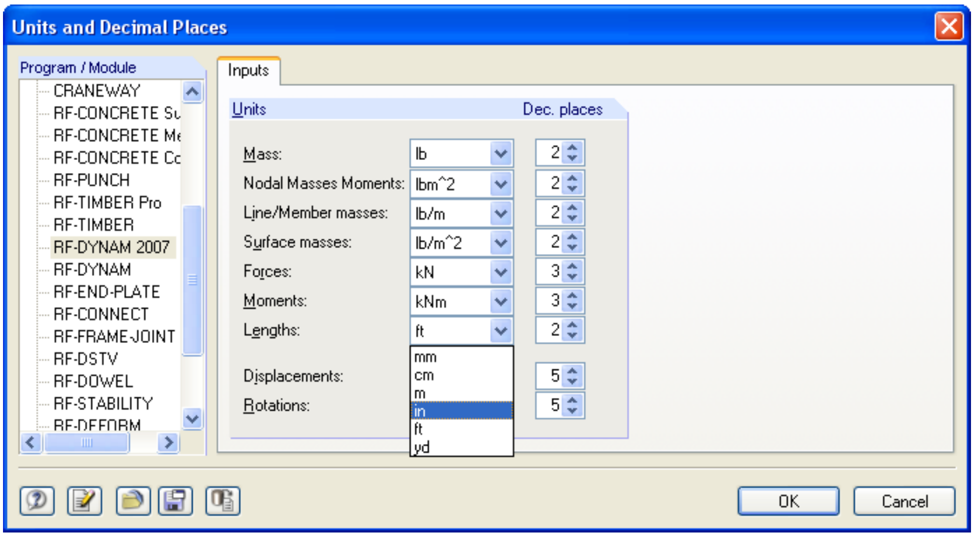


Figure 3.38: Dialog *Units and Decimal Places*

3.6.3 Help

[Alt+H]

This function calls up the help that goes from the manual, but is supposed to be more current than the printed version.

4. Results

4.1 Graphic Display of Results

After the calculation you can switch to the graphic display of results using the [Graphic] button. The current RF-DYNAM case is set by default here.

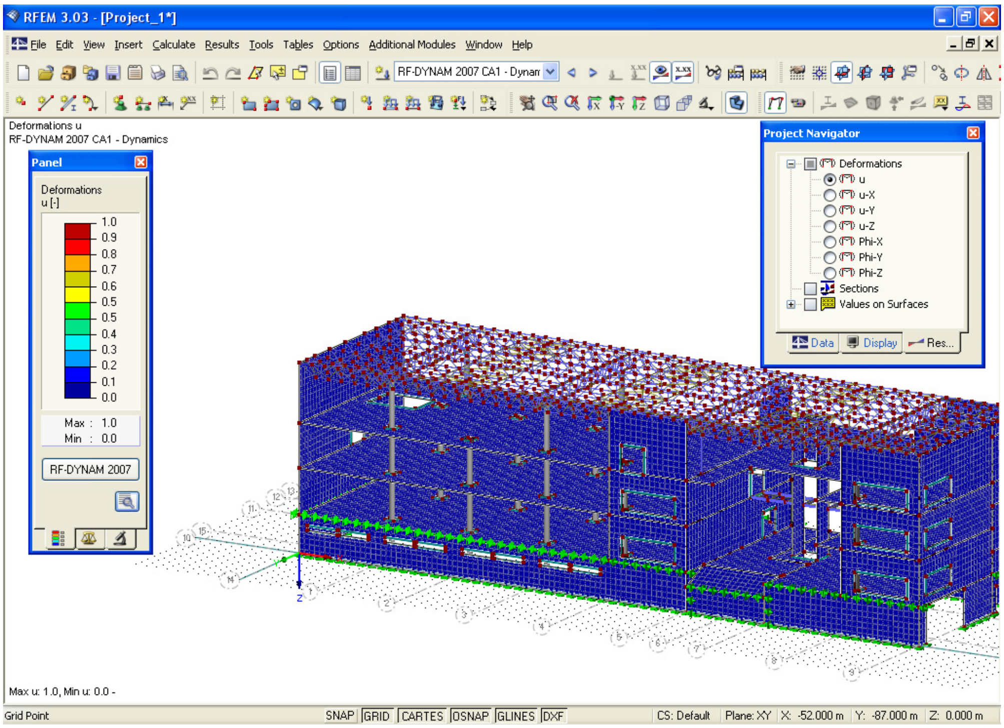


Figure 4.1: Graphic Display of Results in RFEM Work Window

If you activate the [Results on/off] button in the toolbar, the diagram of the first natural frequency of a given structure will be displayed in the window and the result panel as well.

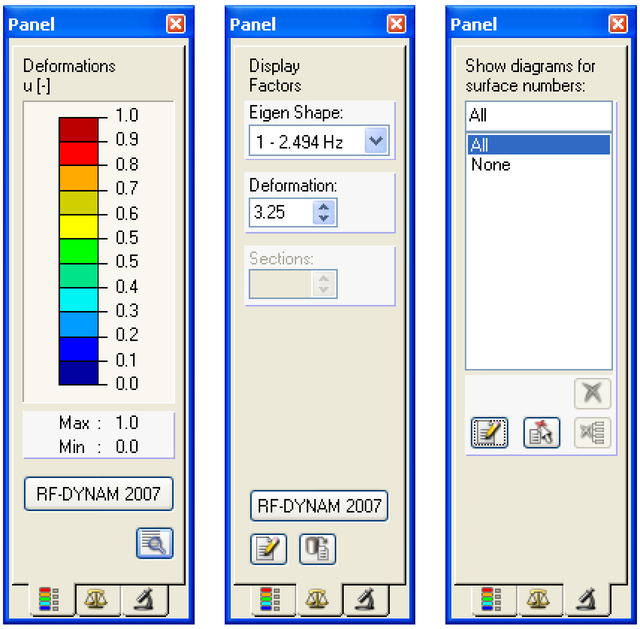
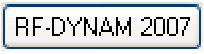


Figure 4.2: Result Panel of RF-DYNAM 2007

The panel consists of three registers. In the first register you can see the color spectrum of the total eigenmodes deformation standardized to 1.

In the second register you can select in the boxes *Eigen Shape* and *Deformation* the eigenmode that you want to display and the factor for the display magnification.

In the last register you can select particular objects that you want to display.



You can return to the RF-DYNAM module using the [RF-DYNAM 2007] button in the panel.

The [Print] button enables you to directly print the graphic display of results or to incorporate it to the printout report (like all other RFEM displays).

4.2 Printout

If you want to print numeric results from RF-DYNAM, you must return to the main RFEM program at first and then call up the [Current Printout Report] function here.

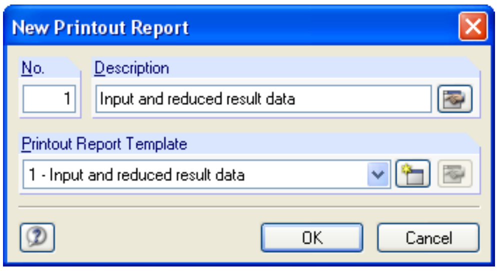


Figure 4.3: Dialog *New Printout Report*

The dialog is displayed where you can enter the description of the new printout report. The report can be adapted from the default *Template.* The report together with RF-DYNAM data is created after clicking on the [OK] button.

Please note that the printout report contains the data from RFEM, RF-DYNAM and other add-on modules. Therefore, it is recommended to reduce the report contents and select only particular required data to be printed, in order to avoid unnecessary amount of data.

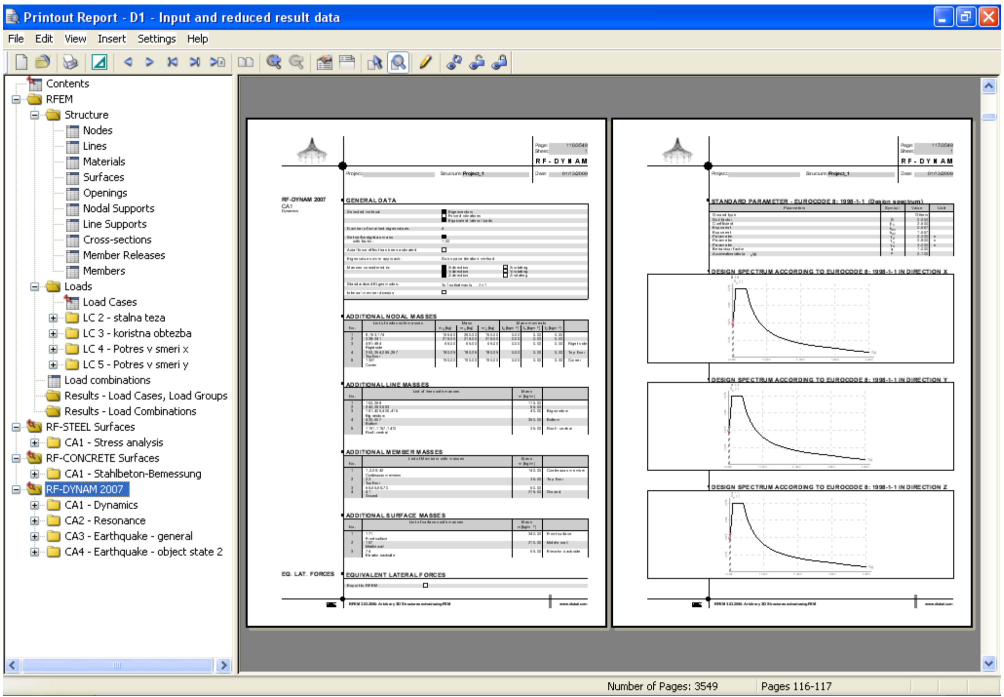


Figure 4.4: Input Data and RF-DYNAM Results in Printout Report

Various functions for the protocol setup and layout are available in the report. They are described in detail in the RFEM manual. The RF-DYNAM 2007 data can be selected for printing also in the special dialog *Printout Report Selection* that you call up by clicking on the button [Select Topics for Printout Report] in the printout report toolbar. RF-DYNAM 2007 can be set in the left part of this dialog in the *Program / Modules* section.

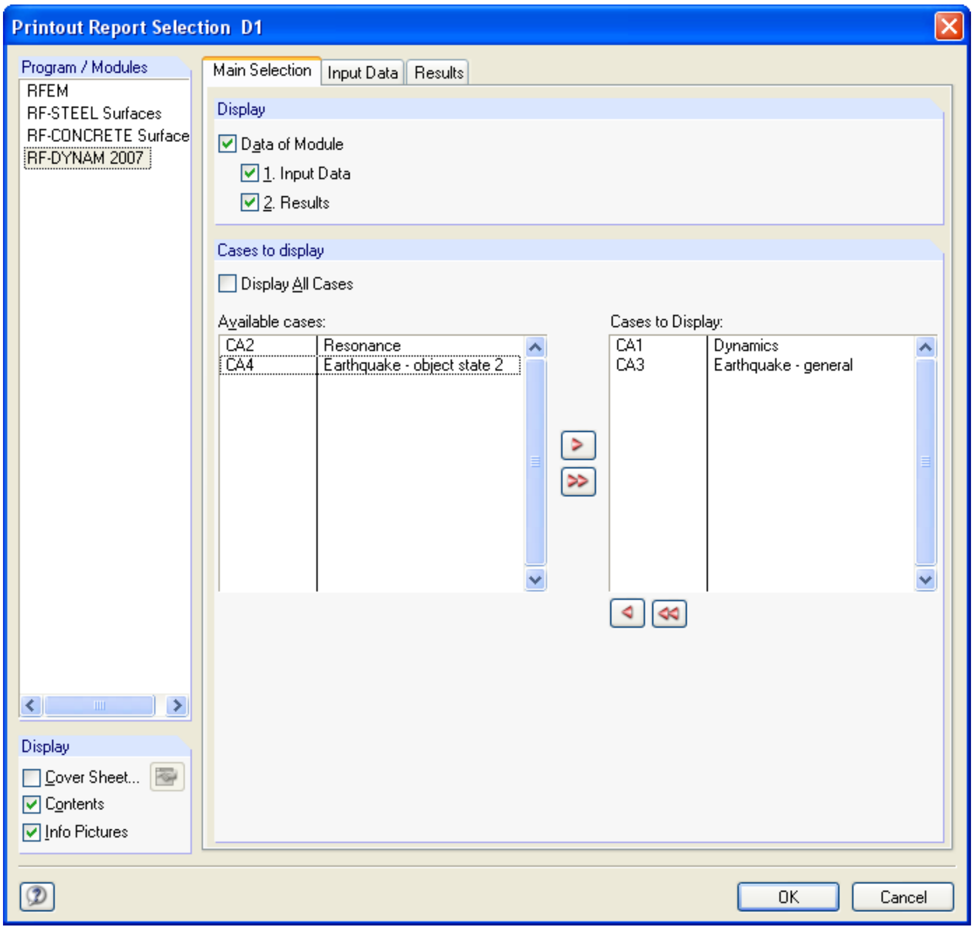
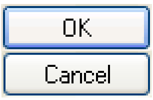


Figure 4.5: Data Selection from RF-DYNAM 2007 to Printout Report, Register *Main Selection*

In the register *Main Selection* in the section *Display* you tick the main chapters that you want to display in the printout report. If you do not select *Display All Cases*, the relevant register with the detailed selection of their subchapters disappears. In the section *Cases to display* you either tick the box *Display All Cases* or select only particular cases from the list *Available cases* and add them to the list *Cases to Display* in the right part of the dialog using the button [Add Selected Case(s) →]. You can remove them from the list using the buttons [← Remove Selected Case from List] and [Give Back all Cases].



You can confirm the selection by the [OK] button in each register of this dialog or you can cancel it by the [Cancel] button, if necessary. Then the dialog closes.

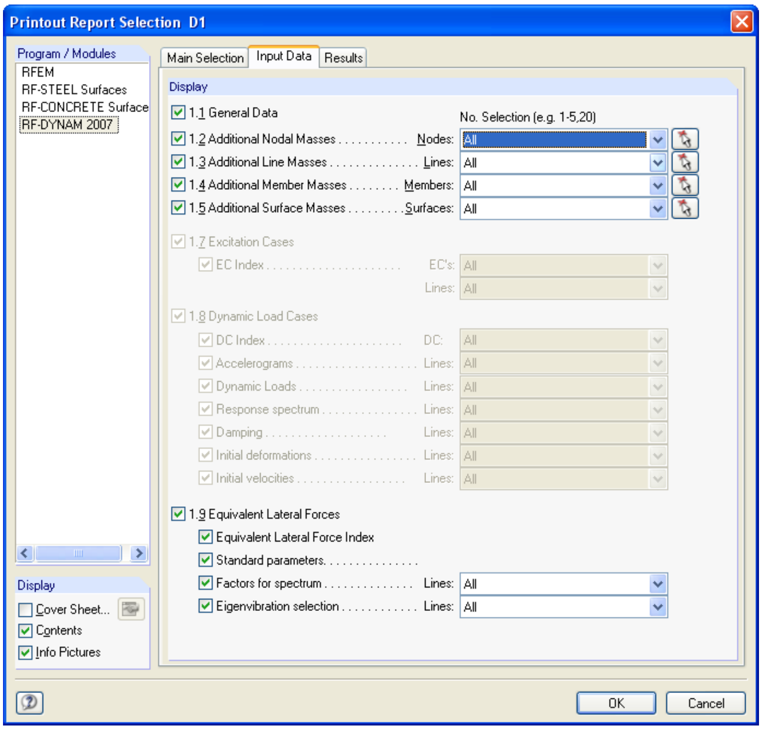


Figure 4.6: Data Selection from RF-DYNAM 2007 to Printout Report, Register *Input Data*

In the register *Input Data* you can decide which general data, additional masses and also equivalent loads will be displayed in the printout report. The selection of particular object numbers can be also done in this way: click in a given box on the button [▼], select an empty line and then enter the required numbers.

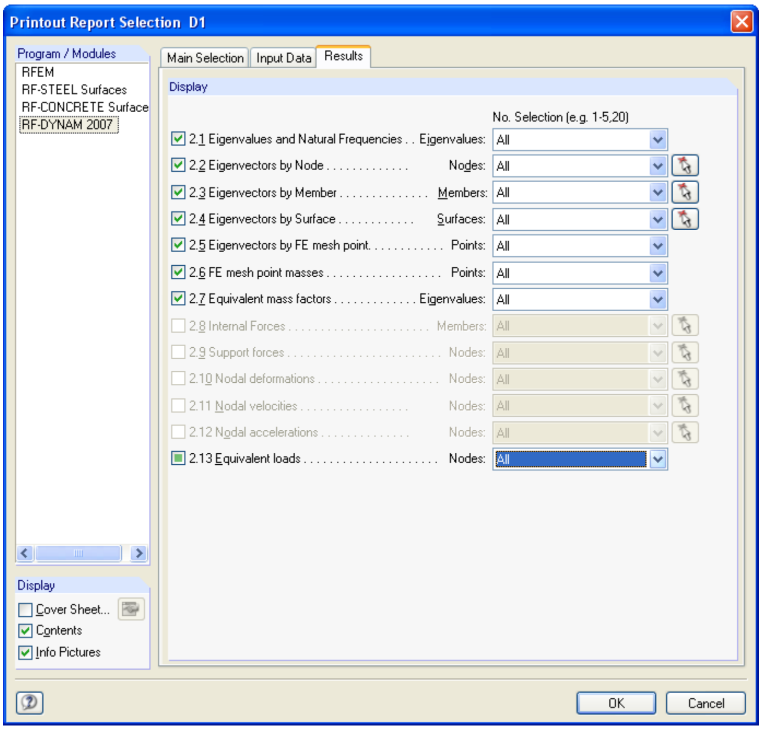


Figure 4.7: Data Selection from RF-DYNAM 2007 to Printout Report, Register *Results*

In the register *Results* you can also select either *All* or only some parts of the data for the printout report.

5. Theory

In this chapter we briefly explain some theoretical principles to enable better understanding of RF-DYNAM processes. This chapter does not substitute the dynamics textbook, but wants to recall some connections and to stimulate further research. Therefore, we would like to ask our users to understand that the existing subject can not be elaborated here in detail and that the textbook interpretation would exceed the scope of this program description.

At first we briefly describe the basic equation for the solving of eigenvalues. Then, we go in for the calculation of kinetically equivalent masses, participation factors and equivalent masses in separate sections. Finally, we present the thematically oriented example in every section.

Equilibrium equation for static structures

The structure reacts to statically acting forces by a deformation. We assume that the structure is inactive before and after loading.

Generally, we can observe a proportional relation between load and deformation. The relation between both quantities is in principle non-linear, but can be regarded as linear for most cases in our intentions. The structural stiffness comes in between load and deformation as the proportionality factor, hence the following relation holds for a static case:

$K_{ij}\, x_i = f_j$

where

K_{ij}	stiffness matrix
x_i	deformation
f_i	load

In case of the structure with one degree of freedom i = j = 1.

Calculation of natural frequencies

If the structure has been stirred up to oscillations and then left in this state for some time, we can observe a continuous oscillation of the structure between two energetic states. Therefore holds:

$E_{kinetic} = E_{potential}$

This relation can be expressed by the following equation:

Equation 4.1:

$$M_{ij}\ddot{x}_i + K_{ij} \cdot x_i = \underline{0}$$

The damping is not taken into account in this equation because the dissipative effect is not relevant for the determination of the natural frequency and eigenmode.

Equation (4.1) can be solved so that the following term is substituted to x_i:

Equation 4.2:

$$x_i = C_i e^{\lambda t} = u_i(x)\, c \cos(\omega t - \alpha)$$

The term (2) substituted to the equation (4.1) is given in view of the fact that the term c $\cos(\omega t - \alpha)$ is generally not equal to zero:

Equation 4.3:

$$\left[M_{ij}\left(-\omega^2\right) + K_{ij}\right] u_i(x) = \underline{0}$$

Regarding the fact that the eigenmode equation $u_i(x)$ is not equal to zero, the natural frequency is determined by the following equation.

Equation 4.4:

$$\det\left(K_{ij} - \omega^2 M_{ij}\right) = \underline{0}$$

We met the angular frequency ω already in the equation (4.3). It is connected to the natural frequency of the structure via the following relation: f = 2πω.

We obtain the relevant eigenmode $u_i(x)$ after substituting the natural frequency to the equation (4.3).

Kinetically equivalent masses

The structure with several degrees of freedom having a concentrated or even mass distribution can from the energetic point of view be transfered to a single-mass oscillation generator with an equivalent kinetic mass. Structures with an oscillation damper or slender tower structures make a typical example of this application.
RF-DYNAM calculates this kinetically equivalent mass for each natural frequency.

We present the mentioned theory on the example of a tubular mast.

The motion of the tubular mast is described by the following relation:

$$y(x,t) = y(x) \cdot \sin(\omega t) = Y \cdot \eta(x) \cdot \sin(\omega t)$$

where

y(x,t)	deflection of location x on mast depending on time
ω	angular frequency of structure
$\eta(x)$	eigenmode standardized to 1 in the location of greatest displacement
Y	deflection in the location where kinetically equivalent mass is determined. RF-DYNAM always starts from the deflection in the location of maximum displacement. The location is always standardized to 1 in the display of the eigenmodes.

Then the structure kinetic energy is obtained as follows:

Equation 4.5:

$$E_{kin} = \frac{\omega^2 Y^2}{2}\left[\int_o^L \mu(x)\eta^2(x)dx\right]\cos^2 \omega t$$

where

$\mu(x)$ even mass distribution, the unit [kg/m].

The equation 4.5 expresses kinetic energy of the structural self-weight and additional member masses. It is necessary to add to this energy the energy of individual additional nodal masses m_i:

Equation 4.6:

$$E_{kin} = \frac{1}{2}\sum_{i=1}^{n} m_i \; \omega^2 Y^2 \eta^2(x_i) \cos^2 \omega t$$

We must incorporate all n additional masses into the sum.

Then the total structural kinetic energy can be found as follows:

Equation 4.7:

$$E_{kin} = \omega^2 \; Y^2 \cdot \frac{1}{2}\left[\int_o^L \mu(x)\eta^2(x)dx\right]\cos^2 \omega t + \frac{1}{2}\sum_{i=1}^{N} m_i \cdot \omega^2 \eta^2(x) \cos^2 \omega t$$

The kinetic energy of the equivalent structure of a single-mass oscillation generator is expressed by the following equation:

Equation 4.8:

$$E_{kin} = \frac{1}{2} M \omega^2 \, Y^2 \cos^2 \omega t$$

By comparison of the equations (4.7) and (4.8) we obtain for the kinetically equivalent mass:

Equation 4.9:

$$M = \int_0^L \mu(x)\, \eta^2(x)\, dx + \sum_{i=1}^{n} m_i \, \eta^2(x_i)$$

For the calculaton of kinetically equivalent masses in another place we must multiply the equation (4.9) by the term $Y^2/\eta^2(x)$.

Example

We will calculate the kinetically equivalent mass for the restrained tubular mast. We assume in the following examples KINEQ1 - KINEQ3 that the member is not divided. In example KINEQ4 the member division is considered.

Mast data:

Section: PIPE 508x11 with section area $A=0.0172\ m^2$

Height: $l = 20\ m$

Weight density DYNAM $\gamma = 7.85 \cdot 10^4\ N/m^3$

Even mass distribution: $\mu = \gamma / g \cdot A = 135\ kg/m$

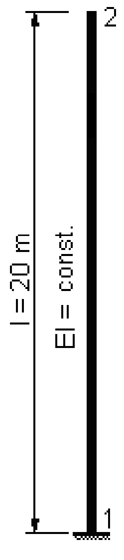


Figure 5.1: Restrained Tubular Mast

KINEQ1:

The mast total mass $M = l\,\mu = 20\ m \cdot 135\ kg/m = 2700\ kg$ is distributed evenly along the whole mast length.

KINEQ2:

The mast total mass $M = l\,\mu = 20\ m \cdot 135\ kg/m = 2700\ kg$ is distributed evenly to both end nodes 1 and 2.

KINEQ3:

The mast self-weight is distributed evenly as outside load on the mast.

With regard to the fact that for all structures we start from a diagonal stiffness matrix, the sum of kinetically equivalent masses is at any rate equal to the acting mass, thus 1350 kg in the node 2.

KINEQ4:

The tubular mast is divided into 5 parts. On this basis we can achieve a more accurate calculation of kinetically equivalent masses. For the calculation of kinetically equivalent mass according to the equation (4.7) the eigenmode is equal to:

$$\eta(\xi) = \frac{1}{2.72423}\left[\sin\lambda\xi - \sinh\lambda\xi + (\cos\lambda\xi - \cosh\lambda\xi)\,\frac{\sinh\lambda - \sin\lambda}{\cosh\lambda - \cos\lambda}\right]$$

where λ = 1,875. Thus we obtain the integral

$$\int_o^L \mu(x)\,\eta^2(x)dx = 0.25$$

and by this also the kinetically equivalent mass:

$$M = \mu \cdot L \int_o^L \eta^2(x)dx = 135\tfrac{kg}{m} \cdot 20m \cdot 0.25 = 675\,kg$$

The result value of the kinetically equivalent mass from the RF-DYNAM 2007 calculation is M = 675.1 kg.

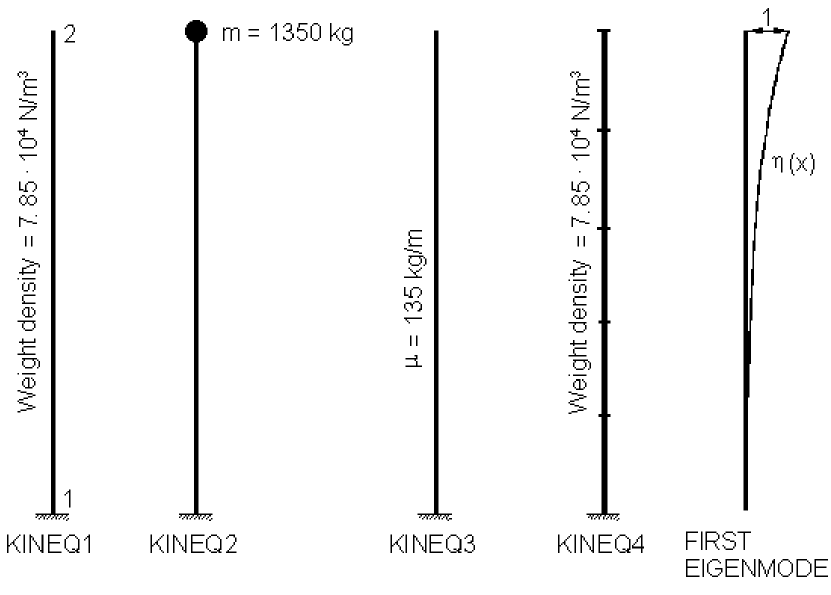


Figure 5.2: Member Mass Distribution in Examples KINEQ1 - KINEQ4

Equivalent masses and participation factors

If you have ticked the box for the calculation of equivalent mass factors in the mask 1.6 *To calculate for eigenvibration* before the calculation has been done, the values of the following quantities are displayed in the result mask 2.7 *Equivalent mass factors*: Modal mass, participation factor, substitute mass and substitute mass factor.

The most important piece of information on the structure presents the distribution of inertial forces H_i that is based on the eigenmode V_i.

The inertial forces are expressed by the following relation:

Equation 4.10

$$H_i = \frac{(V_i^T M)^2}{(V_i^T MV_i)} \cdot S_a \cdot (T_i)$$

where

V_i eigenmode

M stiffness matrix

$S_a(T_i)$ acceleration spectrum of angular frequency ω_i

Using the terms

$M_i = V_i^T M V_i$ modal mass

$L_i = V_i^T M$ participation factor

we obtain from the equation (4.10)

Equation 4.11

$$H_i = \frac{L_i^2}{M_i} \cdot S_a \cdot (T_i) = m_{ei} \cdot S_a \cdot (T_i)$$

where $m_{ei} = L_i^2 / M_i$ equivalent mass of eigenmode $V_{i.}$

We can see from the equations (4.10) and (4.11) that the equivalent mass is independent on the standardized eigenmode V_i. RF-DYNAM standardizes the eigenmode V_i to 1 in the location of the greatest displacement according to

Equation 4.12

$$\sum_{j-1}^{n} V_{ij}^2 = 1$$

where i, j all degrees of freedom of the eigenmode V_i displacement

and calculates on this basis the modal mass matrix, participation factors and substitute masses with equivalent mass factors for the expression of the ratio between equivalent and total mass.

We introduce a practical example of the calculation below.

For more detailed information on this problems see the item [11], page 678, quoted in the Literature at the end of this manual.

Example

A planar three-storey frame consists of weightless columns and beams.

The moment of inertia for all columns makes $I_{2,column}$ = 25 000 cm^4,

for beams $I_{2, beam}$ = 150 000 cm^4.

The column area is A_{column} = 100 cm^2, while beam area makes A_{beam} = 10 000 cm^2.

The beam weight is equally divided into both end nodes (i.e. 12 500 kg).

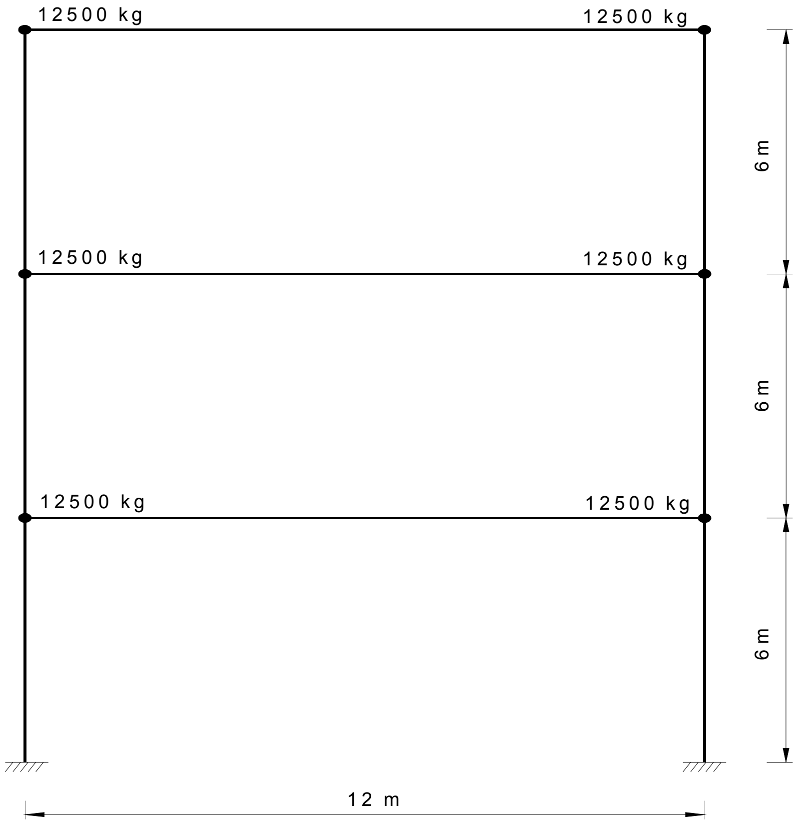


Figure 5.3: Calculation of Equivalent Masses on Three-Storey Frame

Comparison of RF-DYNAM results and results according to the literature:

Eigenmode No.	Equivalent load [kg]	
	RF-DYNAM	Literature [11]
1	66592.9	2.66369*25000 = 66592.25
2	6989.7	0.2769*25000 = 6990.00
3	1417.4	0.05669*25000 = 1417.25

6. Examples

We present in the following chapter a number of examples to explain in more detail how the RF-DYNAM 2007 module works.

In the next example we want to demonstrate the fundamental frequency calculation for a tower with a tapered cross-section.

The examples are taken from the literature. Hence, the comparison of results from the literature with RF-DYNAM 2007 results is important for us in particular.

6.1 Beam

This example was taken from the literature [12], page 20.

A continuous beam that we see in the picture below is analyzed dynamically. The total beam length is 10 m. The continous beam consists of 20 individual beams with bending rigid joints.

The beam cross-section is rectangular, with dimensions d = 0.4 m and B = 0.2 m. Hence, I_{y-} for this cross-section is equal to 1.067E-3 m^4 and area A = 8.0E-2 m^2. The modulus of elasticity makes E = 3.0E+7 kN/m^2.

With regard to the fact that the weight density γ makes 25 kN/m^3, every single beam has the mass $G_i = \gamma\ A\ l\ /\ g = 25000 \cdot 0.08 \cdot 0.5\ /\ 10$ kg = 100 kg.

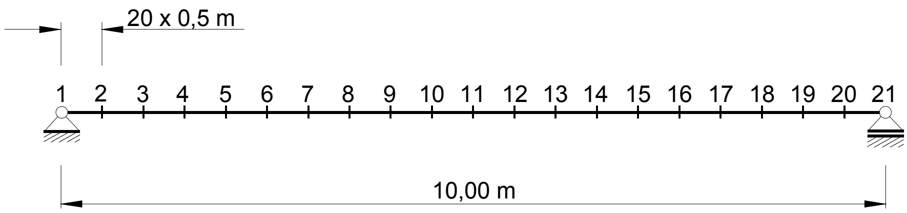


Figure 6.1: Beam Scheme for Example No. 1

From the outline of RF-DYNAM 2007 results we can see that for the nodes 2 - 20 the active mass of 100 kg acts in the Z-axis direction. The nodes 1 and 21 are supported in the Z-axis direction, hence their mass is not regarded as dynamic for the Z-direction. The active mass in the X-axis direction is equal to zero for the node 1, based on the support assignment (the rigid support in the X-direction).

The structure is not supported in the X-axis direction on the node 21, thus the active mass shows the final value lower than 100 kg.

The result accuracy of natural frequencies in RF-DYNAM 2007, compared to the results from the literature, is certainly worth noticing. The results are transparently compared in the next table.

Six lowest natural frequencies f [Hz]		
Natural frequency No.	**RF-DYNAM 2007**	**Literature**
1	6.284	6.283
2	25.137	25.133
3	56.556	56.547
4	86.580	86.580
5	100.535	100.519
6	157.056	157.032

6.2 Truss Girder

The following example was taken from the literature [12], page 29.

In this exercise we want to calculate eigenvalues of the truss structure shown in the picture below. The material has the modulus of elasticity E = 2.06E+8 kN/m², poisson number ν = 0.29 and weight density 7.88 t/m³.

For the girder we have applied the circular profile with a diameter of 4 cm.

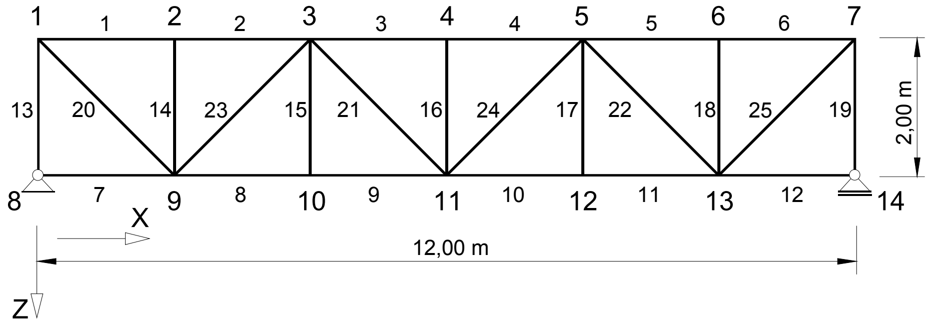


Figure 6.2: Sheme of Truss Girder for Example No. 2

RF-DYNAM 2007 will calculate the following natural frequencies compared to the results from the literature:

Five lowest natural frequencies f [Hz]		
Natural frequency No.	**RF-DYNAM**	**Literature**
1	13.30	13.15
2	22.77	22.57
3	36.20	35.82
4	50.23	49.81
5	51.72	51.37

6.3 Concrete Chimney

This example was taken from the literature [11], page 213. Here, we explain how *member divisions by reason of taper or elastic foundation existence* have effect. The RF-DYNAM 2007 result approaches the result from the literature depending on the selected member division.

The concrete chimney narrows along its length in a rate of approximately 3:1. Hence, it can be regarded as the tapered member. The modulus of elasticity E = 2E+7 kN/m², weight density γ = 25 kN/m³.

The following values apply for the area of the chimney base:

The area A_A makes 14.78 m². Therefore, the even mass distribution will correspond to
$\mu = \gamma A / g = 25000 \cdot 14.78 / 10$ kg/m = 36.95E+3 kg/m.
The moment of inertia I_A is 122.9 m⁴.

The following values apply for the area of the chimney head:

The area A_E makes 4.79 m². Therefore the even mass distribution will correspond to
$\mu = \gamma A / g = 25000 \cdot 4.79 / 10$ kg/m = 11.973E+3 kg/m.
The moment of inertia I_E is 22.2 m⁴.

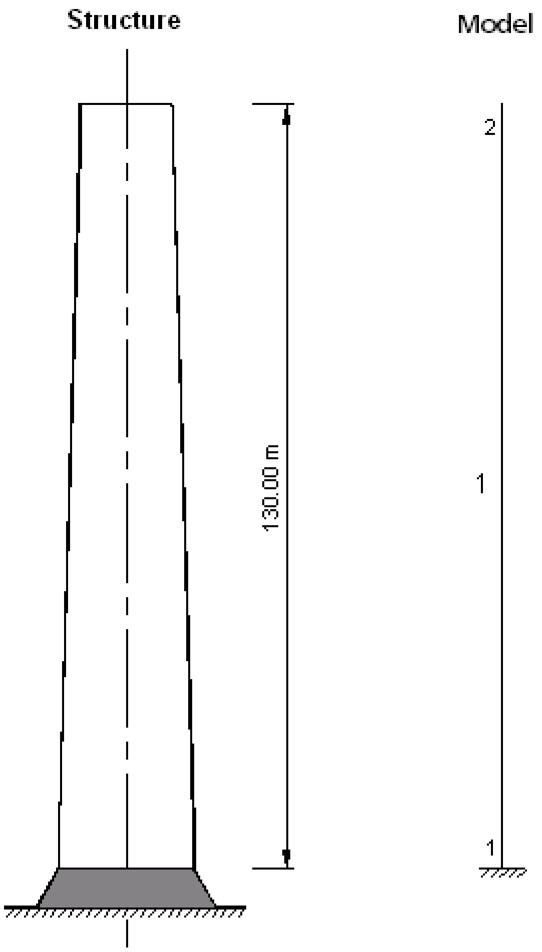


Figure 6.3: Scheme of Concrete Chimney for Example No. 3

The literature quotes for the fundamental frequency of the chimney: **f = 0.367 Hz**.

Fundamental frequency f [Hz] of reinforced concrete chimney	
Number of divisions	Calculated fundamental frequency
2	0.3291
6	0.3600
10	0.3673
20	0.3657
50	0.3641

6.4 Equivalent Seismic Loads according to DIN 4149

In this example we compare equivalent seismic loads calculated in RF-DYNAM 2007 according to the DIN 4149 standard with a manual calculation. In the following tables we can see input data entered in the main program RFEM.

Figure 6.4: Structural Model for Example No. 4: Equivalent Seismic Loads

NODES

Node No.	Node Type	Reference Node	Coordinate System	Node Coordinates X [m]	Z [m]	Comment
1	Standard	-	Cartesian	0.000	-100.000	
2	Standard	-	Cartesian	0.000	-87.500	
3	Standard	-	Cartesian	0.000	-62.500	
4	Standard	-	Cartesian	0.000	-37.500	
5	Standard	-	Cartesian	0.000	-12.500	
6	Standard	-	Cartesian	0.000	0.000	Fixed Restraint

LINES

Line No.	Line Type	Nodes No.	Line Length l [m]		Comment
1	Polyline	2.1	12.500	Z	
2	Polyline	3.2	25.000	Z	
3	Polyline	4.3	25.000	Z	
4	Polyline	5.4	25.000	Z	
5	Polyline	6.5	12.500	Z	

MATERIALS

Material No.	Material Description	Modulus of Elasticity E [kN/cm^2]	G-Modulus G [kN/cm^2]	Poisson Number μ [-]	Weight Density γ [kN/m^3]	Temperature Expansivity Factor α [1/°C]	Factor γM
1	Concrete C20/25	3000.00	1400.00	0.200	25.00	1.0000E-05	1.000

NODAL SUPPORTS

Support No.	On Nodes No.	Rotation [°] around Y	Restraint resp. Spring uX'	uZ'	φY'	Comment
1	6	0.00	X	X	X	

CROSS-SECTIONS

Cross-Section No.	Cross-Section - Description	Material No.	Bending Moment of Inertia Iy [m^4]	Cross-Section Areas [m^2] Axial A	Shear Az	Comment
1	P1	1	12.667	100.000		
2	P2	1	19.000	100.000		
3	P3	1	25.333	100.000		
4	P4	1	31.667	100.000		

MEMBERS

Member No.	Line No.	Member Type	Cross-Section No. Start	End	Release No. Start	End	Excent. No.	Division No.	Length L [m]	
1	1	Beam	4	4	-	-	-	-	12.500	Z
2	2	Beam	4	4	-	-	-	-	25.000	Z
3	3	Beam	3	3	-	-	-	-	25.000	Z
4	4	Beam	2	2	-	-	-	-	25.000	Z
5	5	Beam	1	1	-	-	-	-	12.500	Z

For this example we have selected the following parameters in accordance with the DIN 4149 standard:

Ground condition: A-R

Importance factor γ_I: 1.0

Design ground acceleration a_g: 1.00 m/s²

Spectral acceleration factor β_0: 2.5

Correction damping factor η: 1.00

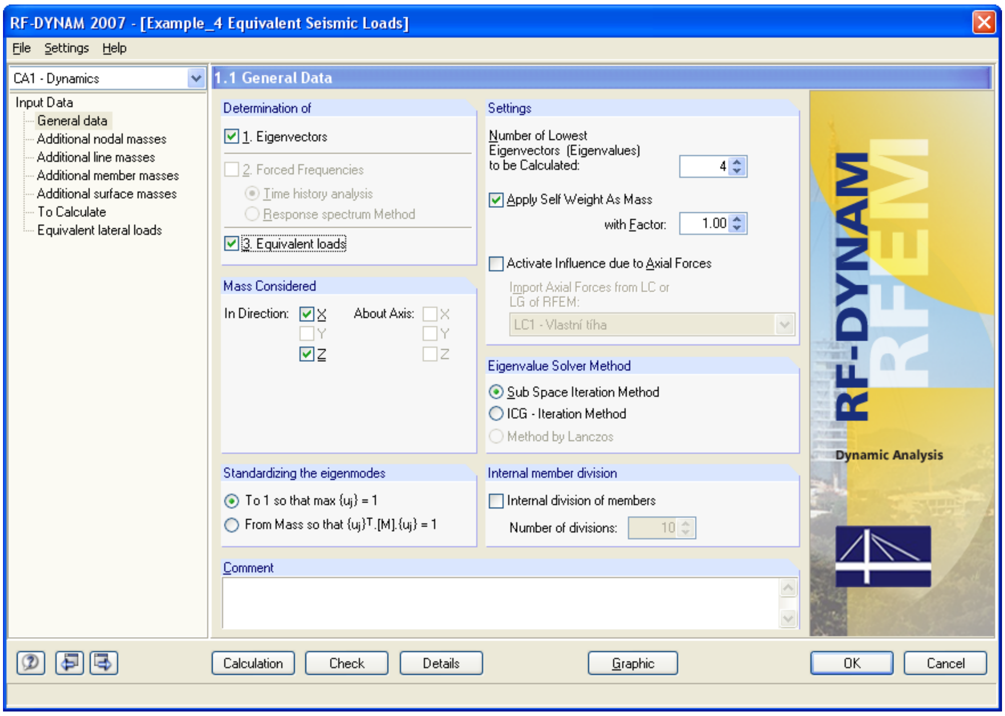


Figure 6.5: General Data without Application of Self Weight and with *Mass Considered* in Directions X and Z

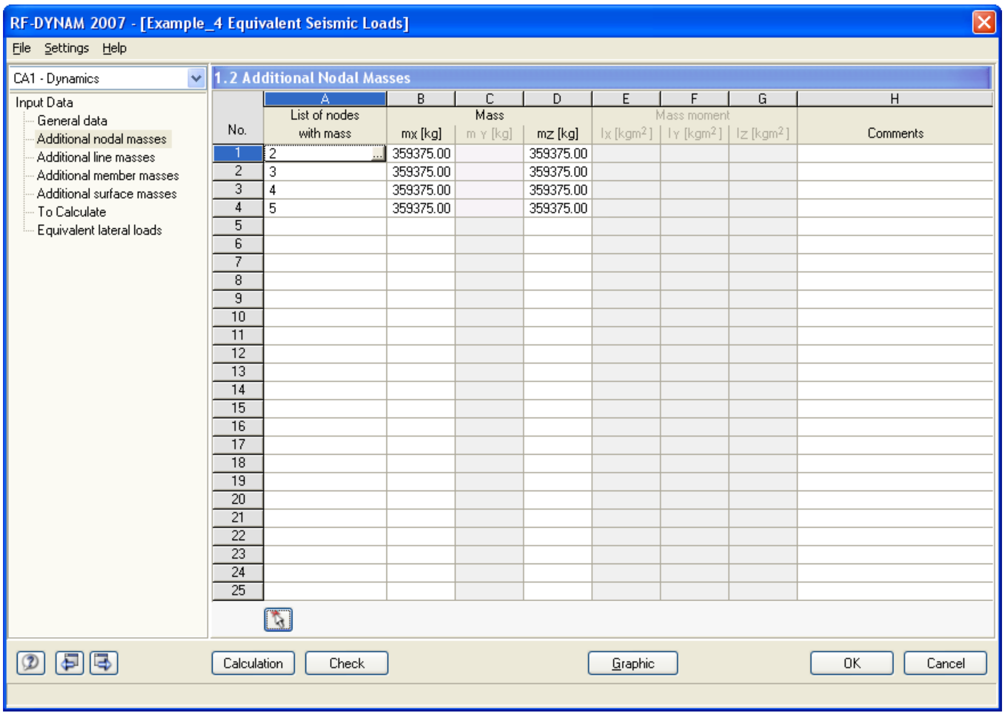


Figure 6.6: Mass Distribution on Nodes 2 to 5 with 359 375 kg each

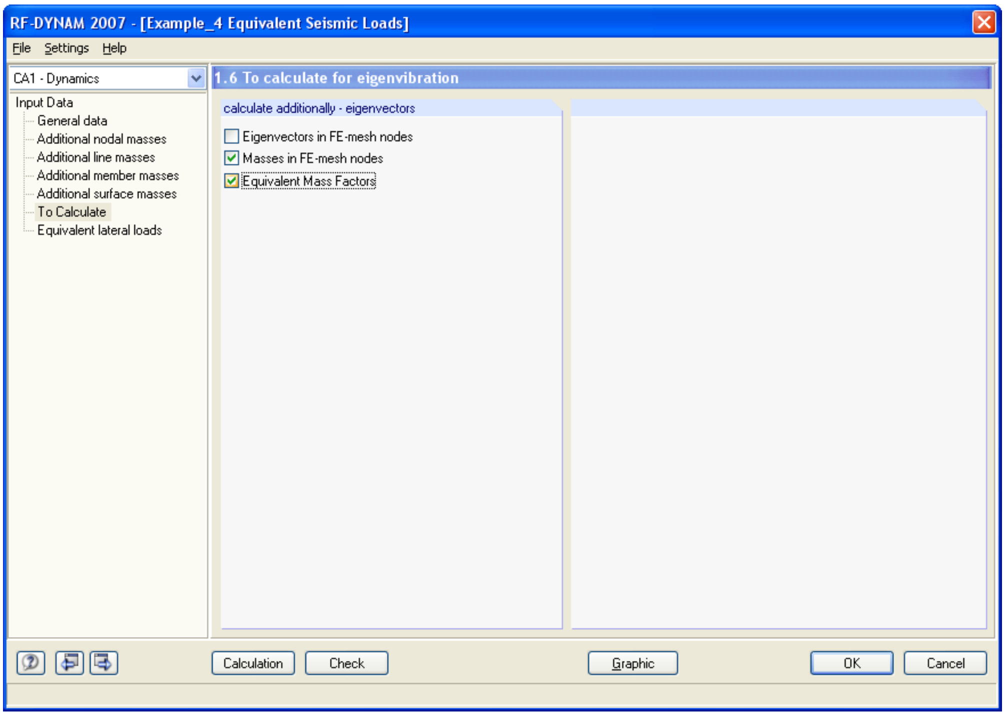


Figure 6.7: Mask 1.6 *To calculate for eigenvibration*

To find out the number of eigenmodes that is necessary to consider, we recommend in the mask 1.6 *To calculate for eigenvibration* to calculate additionally the equivalent mass factors and masses in FE-mesh nodes. In principle, there should be so many eigenmodes that the sum of effective equivalent masses makes at least 90% of the effective total mass which corresponds to the sum of equivalent mass factors 0.90.

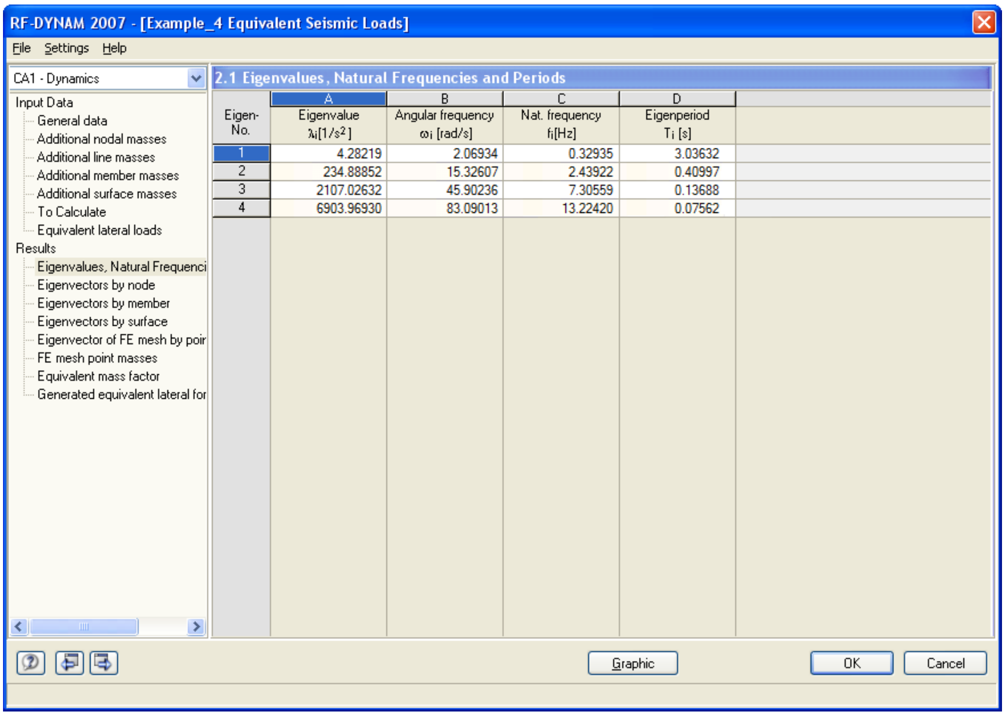


Figure 6.8: Mask 2.1 *Eigenvalues, Natural Frequencies and Periods*

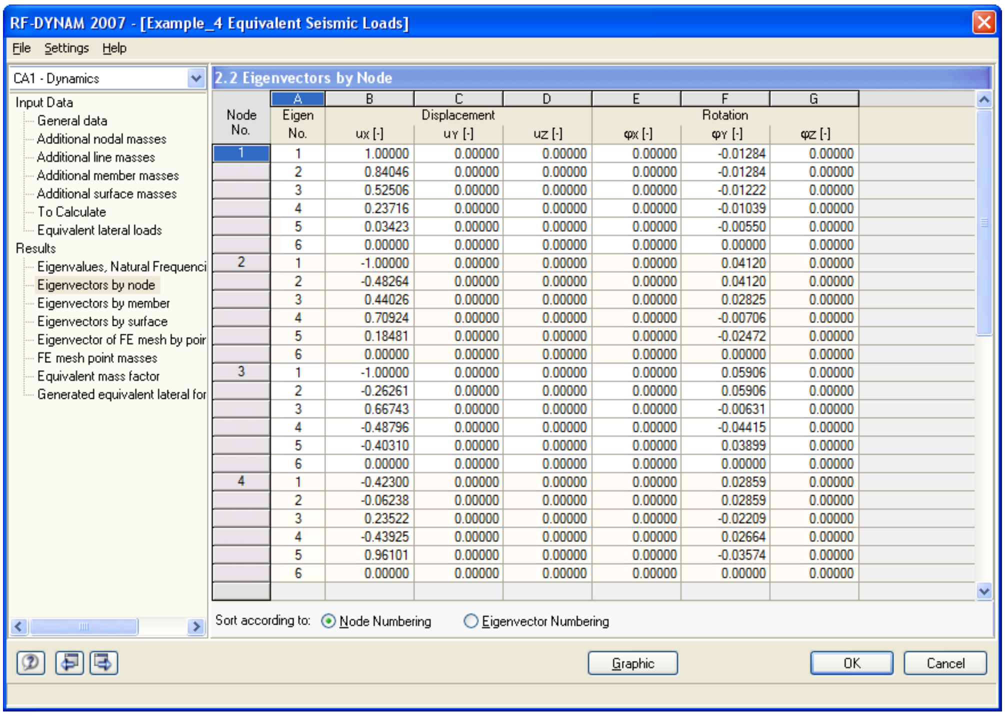


Figure 6.9: Mask 2.2 *Eigenvectors by Node*

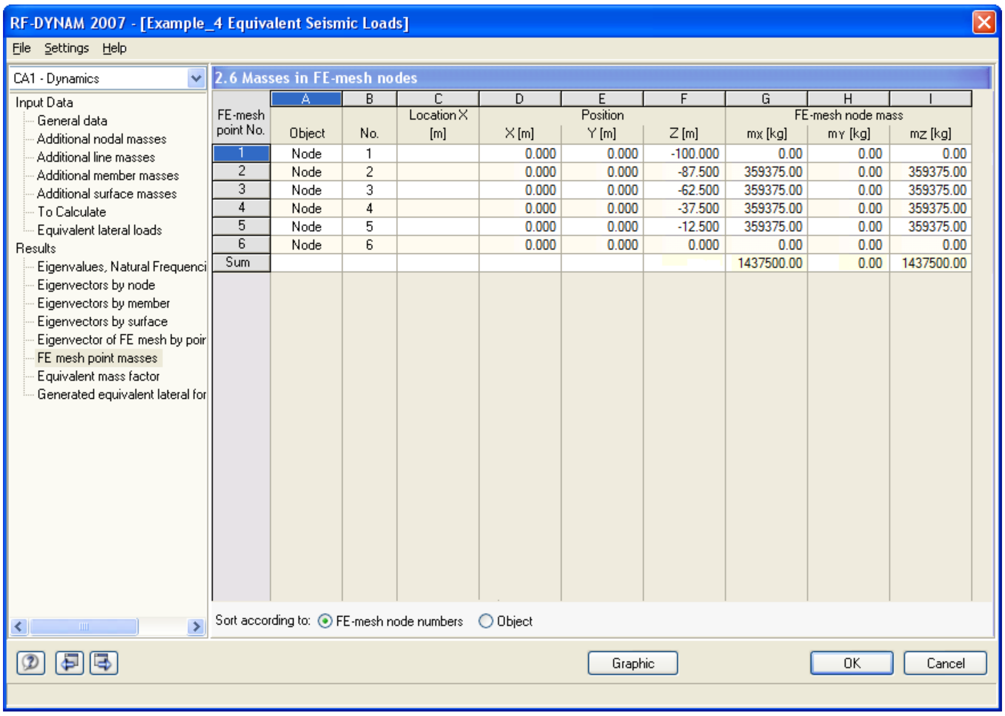


Figure 6.10: Mask 2.6 *Masses in FE-mesh nodes*

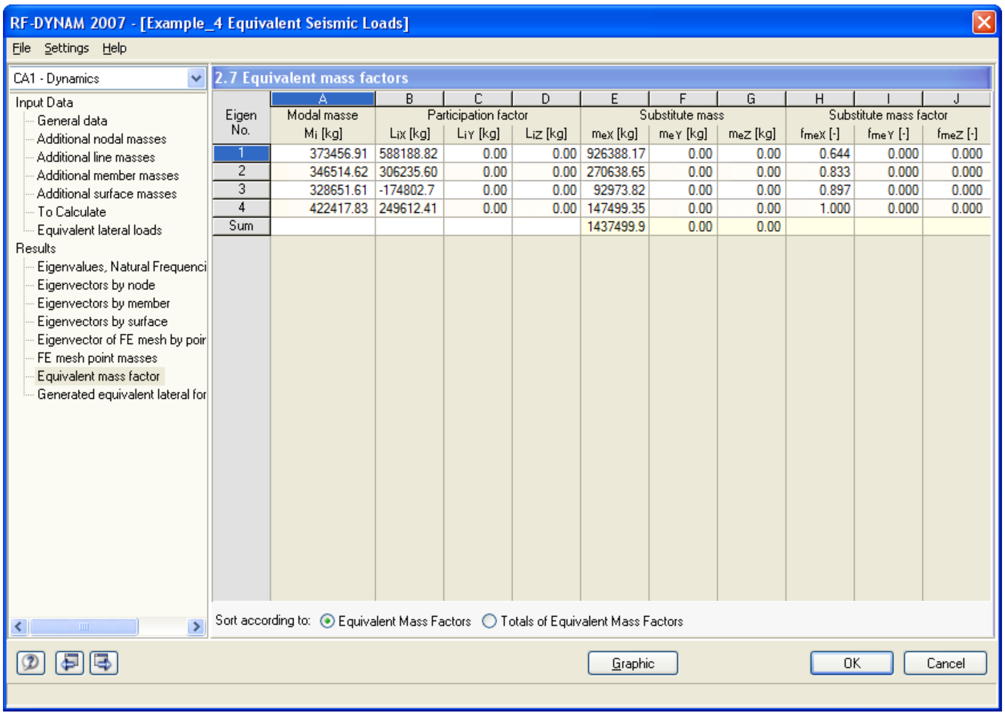


Figure 6.11: Mask 2.7 *Equivalent Mass Factors*

In the mask 2.7 *Equivalent mass factors*, the sum is displayed in the column H *Substitute mass factor*. It is apparent that at least 90% of the total effective mass was obtained by four eigenmodes.

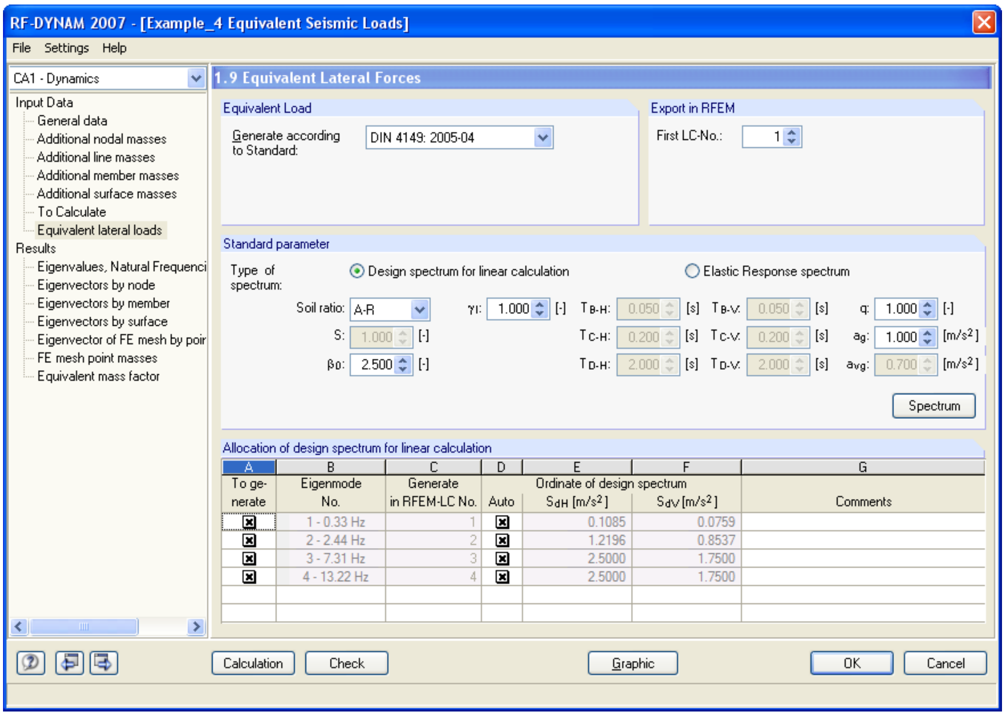
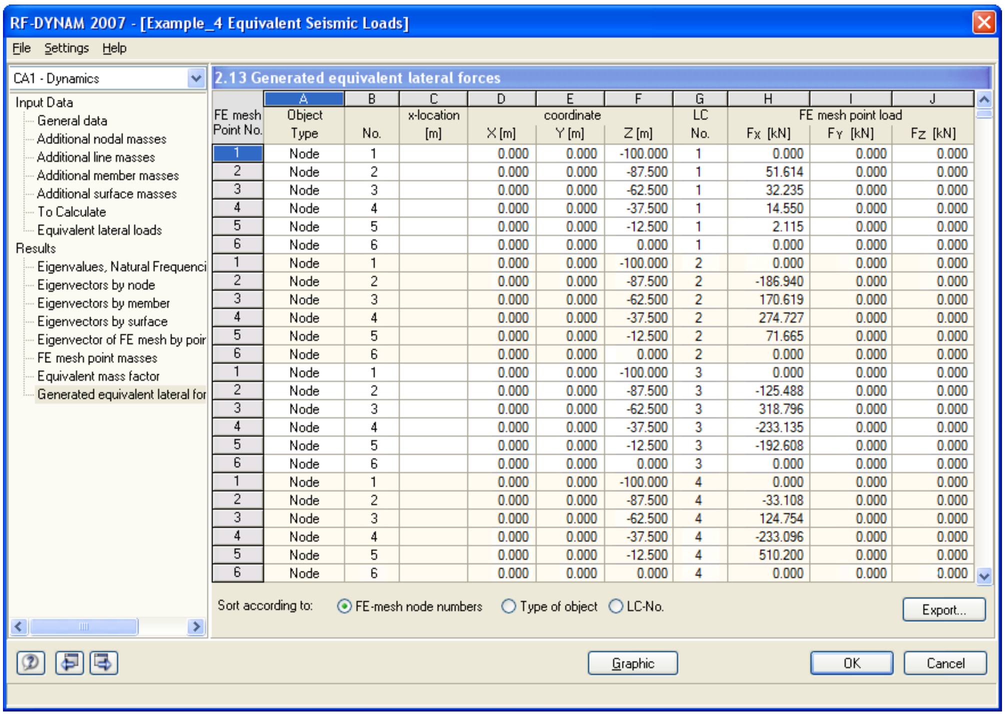


Figure 6.12: Mask 1.9 *Equivalent Lateral Forces*

In the mask 1.9 *Equivalent Lateral Forces* for the determination of standard parameters we select all eigenmodes in the column A. Equivalent loads are then automatically written to RFEM load cases 1 - 4 (see column C).



FE mesh Point No.	A Object Type	B No.	C x-location [m]	D X [m]	E coordinate Y [m]	F Z [m]	G LC No.	H Fx [kN]	I FE mesh point load Fy [kN]	J Fz [kN]
1	Node	1		0.000	0.000	-100.000	1	0.000	0.000	0.000
2	Node	2		0.000	0.000	-87.500	1	51.614	0.000	0.000
3	Node	3		0.000	0.000	-62.500	1	32.235	0.000	0.000
4	Node	4		0.000	0.000	-37.500	1	14.550	0.000	0.000
5	Node	5		0.000	0.000	-12.500	1	2.115	0.000	0.000
6	Node	6		0.000	0.000	0.000	1	0.000	0.000	0.000
1	Node	1		0.000	0.000	-100.000	2	0.000	0.000	0.000
2	Node	2		0.000	0.000	-87.500	2	-186.940	0.000	0.000
3	Node	3		0.000	0.000	-62.500	2	170.619	0.000	0.000
4	Node	4		0.000	0.000	-37.500	2	274.727	0.000	0.000
5	Node	5		0.000	0.000	-12.500	2	71.665	0.000	0.000
6	Node	6		0.000	0.000	0.000	2	0.000	0.000	0.000
1	Node	1		0.000	0.000	-100.000	3	0.000	0.000	0.000
2	Node	2		0.000	0.000	-87.500	3	-125.488	0.000	0.000
3	Node	3		0.000	0.000	-62.500	3	318.796	0.000	0.000
4	Node	4		0.000	0.000	-37.500	3	-233.135	0.000	0.000
5	Node	5		0.000	0.000	-12.500	3	-192.608	0.000	0.000
6	Node	6		0.000	0.000	0.000	3	0.000	0.000	0.000
1	Node	1		0.000	0.000	-100.000	4	0.000	0.000	0.000
2	Node	2		0.000	0.000	-87.500	4	-33.108	0.000	0.000
3	Node	3		0.000	0.000	-62.500	4	124.754	0.000	0.000
4	Node	4		0.000	0.000	-37.500	4	-233.096	0.000	0.000
5	Node	5		0.000	0.000	-12.500	4	510.200	0.000	0.000
6	Node	6		0.000	0.000	0.000	4	0.000	0.000	0.000

Figure 6.13: Mask 2.13 *Generated Equivalent Lateral Loads*

Individual equivalent loads can be shown transparently in the RFEM graphic window in the display of load cases 1 - 4.

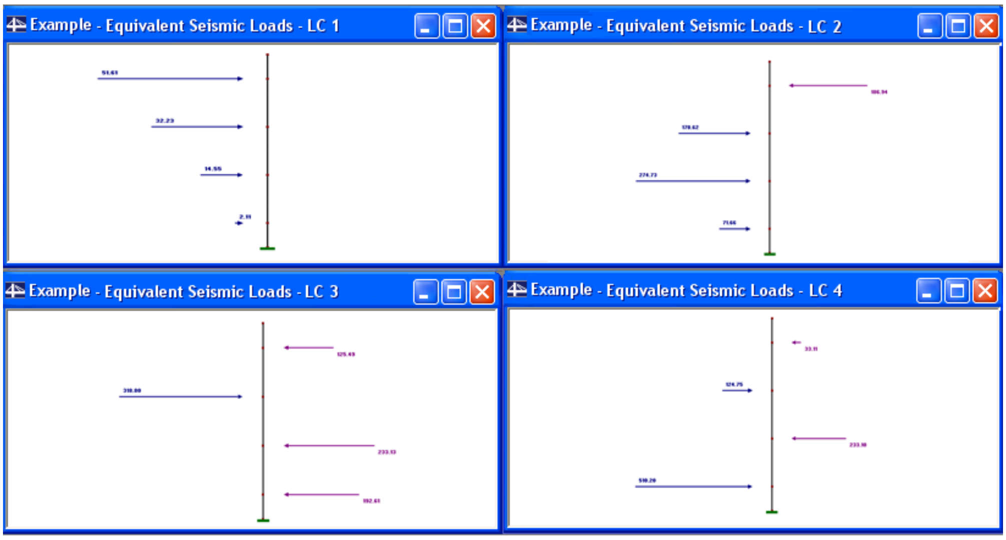


Figure 6.14: Graphic Display of Exported Equivalent Load Cases 1 - 4

Now we can compare the calculated equivalent seismic loads with the values calculated manually.

Node	Mass [kg]	Normed Shift ψ_{1i} NS1	Normed Shift ψ_{2i} NS2	Normed Shift ψ_{3i} NS3	Normed Shift ψ_{4i} NS4
1	0.00	1.00000	-1.00000	-1.00000	-0.42300
2	359375.00	0.84046	-0.48264	-0.26261	-0.06238
3	359375.00	0.52506	0.44026	0.66743	0.23522
4	359375.00	0.23716	0.70924	-0.48796	-0.43925
5	359375.00	0.03423	0.18481	-0.40310	0.96101
6	0.00	0.00000	0.00000	0.00000	0.00000
$\Sigma m_j * \psi_{ji}$		588265	306069	-174743	249622
$\Sigma m_j * \psi_j^{i2}$		373562	346418	328836	422517
ωi [Hz]		2.06934	15.32607	45.90236	83.09013
fi [Hz]		0.32935	2.43922	7.30559	13.22420
Ti [s]		3.03632	0.40997	0.13688	0.07562
S_e		0.1085	1.2196	2.5000	2.5000

When we start from the equivalent mass $m_{e,j}$ and the ratio factor L_j

$$m_{e,j} = \frac{\left(\sum m_i \cdot \psi_{j,i}\right)^2}{\sum m_i \cdot \psi_{j,i}^{\;2}}$$

$$L_j = \sum m_i \cdot \psi_{j,i}$$

and the equivalent load

$$F_{j,i} = \frac{m_{e,i}}{L_j} \cdot m_i \cdot \psi_{j,i} \cdot S_e$$

we get the following results that are identical with the equivalent loads calculated in RF-DYNAM 2007:

Node	Eigenmode 1	Eigenmode 2	Eigenmode 3	Eigenmode 4
	$m_{e,j}$=926365[kg] $F_{,j,I}$ [N]	$m_{e,j}$=270419[kg] $F_{,j,I}$ [N]	$m_{e,j}$=92858[kg] $F_{,j,I}$ [N]	$m_{e,j}$=147476[kg] $F_{,j,I}$ [N]
1	0	0	0	0
2	51606.496	-186899.042	125377.2	-33110.9255
3	32240.0909	170487.677	-318649.346	124853.349
4	14562.2595	274648.344	232965.457	-233151.235
5	2101.81372	71566.4098	192450.971	510098.276
6	0	0	0	0

6.5 Modal Frame Analysis

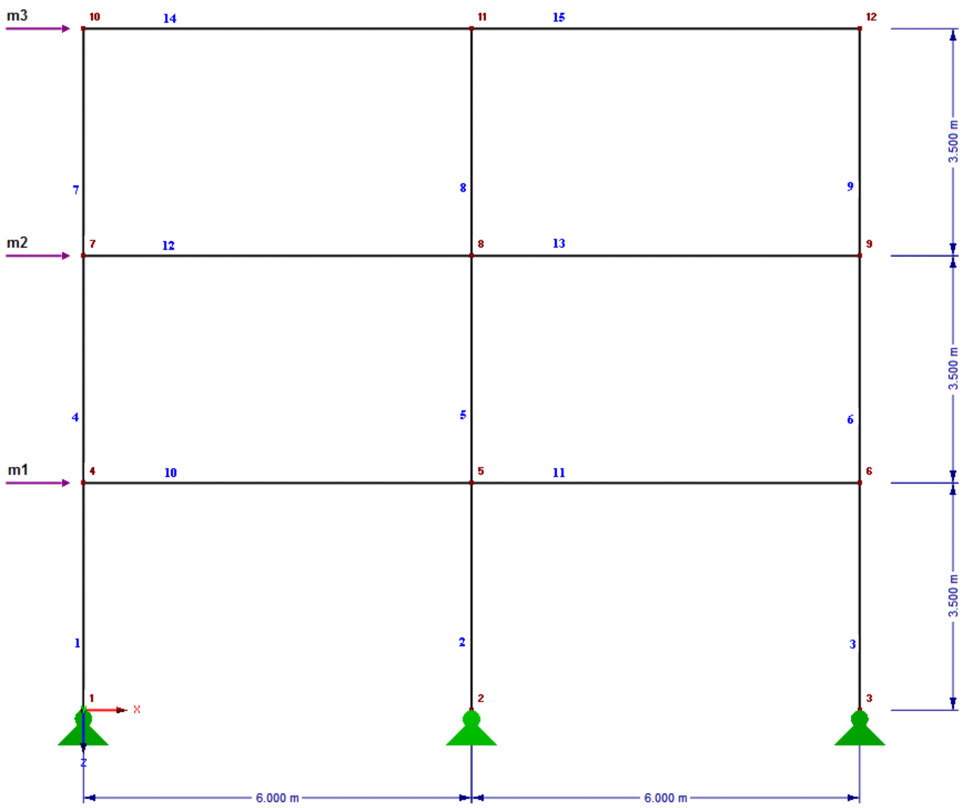


Figure 6.15: Scheme for Example No. 5: Modal Frame Analysis

This example was taken from the literature [13], page 99 ff and page 117 ff.

Members 14, 15: EI_R = 32 000 KNm²

Members 10, 11, 12, 13: 2 EI_R = 64 000 KNm²

Members 1, 4, 7 a 3, 6, 9: EI_S = 30 000 KNm²

Members 2, 5, 8: 2 EI_S = 60 000 KNm²

m1 = 8 t

m2 = m3 = 30 t

In this example we calculate the first three eigenmodes.

The calculation of the first three eigenperiods:

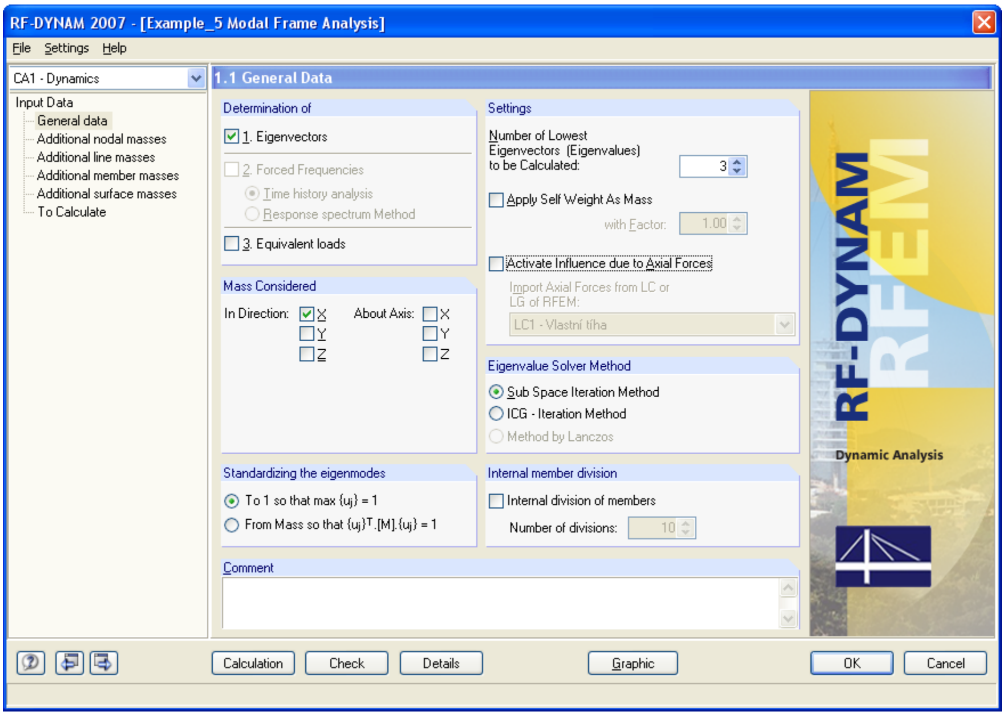


Figure 6.16: Mask 1.1 *General Data* without Self Weight Application

Conversion of masses m1, m2 and m3 into additional nodal masses:

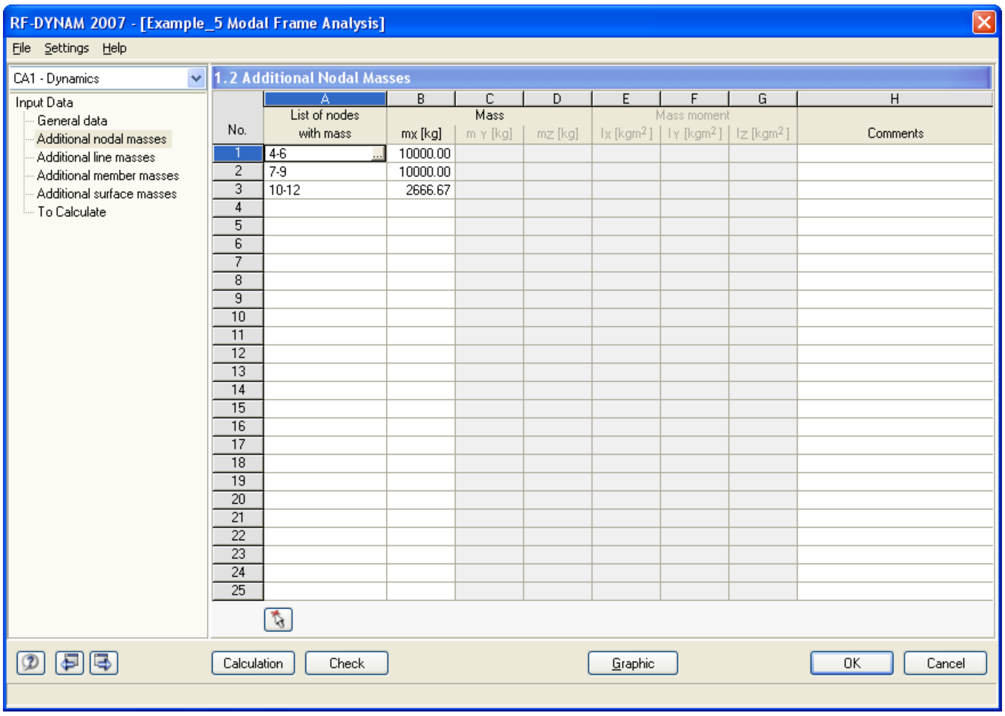


Figure 6.17: Mask 1.2 *Additional Nodal Masses*

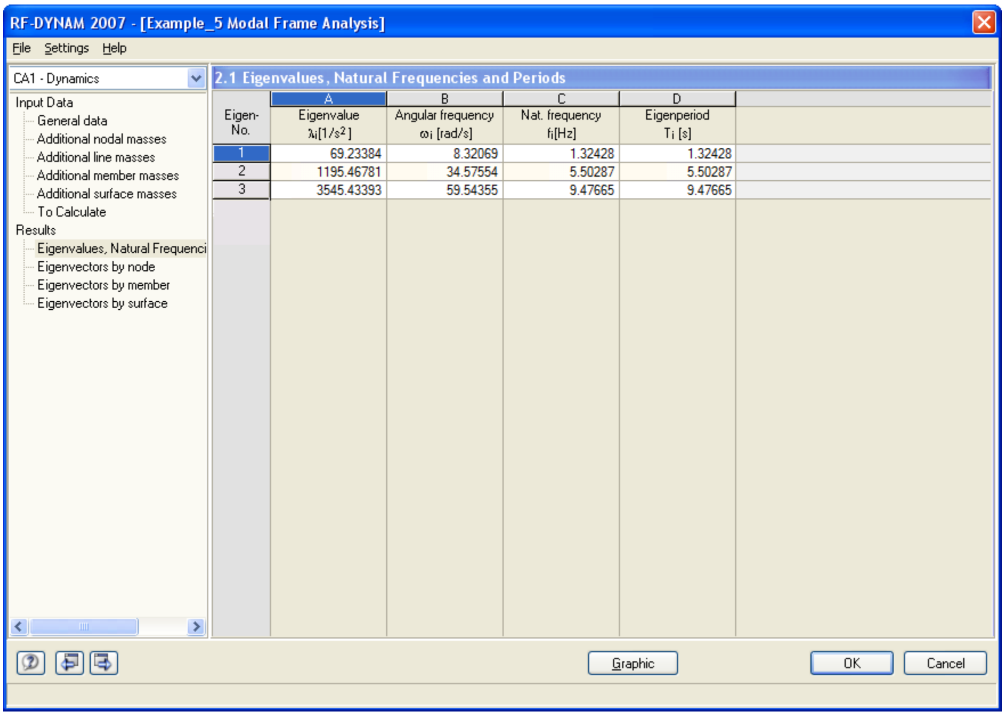


Figure 6.18: Table 2.1 *Eigenvalues, Natural Frequencies and Periods*

The following table compares RF-DYNAM 2007 results with results from the literature:

Eigenmode No.	**Eigenperiod T_i [s]**	
	DYNAM	**Literature [13]**
1	0.75513	0.755128
2	0.18172	0.181723
3	0.10552	0.105522

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