**Version
April 2006**

Program

RF-COMBI 2006

**Generating Load Groups
and Load Combinations**

User Manual

Contents

1. Introduction

1.1 About RF-COMBI 2006

Dear RF-COMBI users,

The new generations of standards require multiple combinations of load cases to be investigated. For large spatial structures, it can be extremely time-consuming and difficult to compose all combinations manually. The add-on module RF-COMBI automatizes this job.

RF-COMBI generates load groups and load combinations according to German and European standards. These standards are implemented:

- DIN 1055-100 [1]
- DIN 18800 [2]
- EN 1990 [3] together with National Application Documents

RF-COMBI imports the load cases which have been defined in RFEM, allocates them to norm-compliant actions and creates all load groups or load combinations that have to be considered according to the selected standard. These load groups or load combinations can then be exported to RFEM for analysis.

It is not always necessary to consider all generated load groups or load combinations. Thus, they can be limited automatically or manually before exporting them to RFEM. The RFEM calculation will be faster.

RF-COMBI stands out by the following program features:

- Generation of RFEM load groups for non-linear analyses, including imperfections
- Generation of RFEM load combinations for linear analyses
- Option to characterize "alternative" load cases
- Possibility to define imperfection-type load cases dependent on 'genuine' load cases
- Possibility to enter and to save user-defined coefficients in addition to the default values
- Two ways to present the results: *Results by Actions* according to the definition to check the generated results, and *Results by Load Groups*/*Combinations* according to the layout of the RFEM data navigator.
- Clearly laid-out summary of the results, including the coefficients applied and information on actions and load cases.
- Reduction of load groups to be created by examining RFEM results
- Printout report with individual options for presentation

We wish you much success using RF-COMBI.

Your ING.-SOFTWARE DLUBAL Team

1.2   The RF-COMBI Team

RF-COMBI was developed by the following team.

Program Coordination:

- Dipl.-Ing. Georg Dlubal
- Ing. Vladimír Pátý

Programming:

- Mgr. Jaroslav Krul

Program Check, Manual, Translation:

- Bc. Tibor Tóth
- Ing. Vladimír Pátý
- Dipl.-Ing. Frank Faulstich
- Dipl.-Ing. (FH) Robert Vogl

1.3   General Survey of the Manual

This manual is organized in several chapters. Although it is assumed that the basics of the load application according the single standards are known, a couple of details on the theoretical background have been included for a better understanding of the functionality.

- **Chapter 1: Introduction**
  This chapter describes the capacities and the range of application of RF-COMBI.

- **Chapter 2: Theoretical Background**
  The theoretical background of RF-COMBI includes the principles and equations of the standards DIN 1055-100, DIN 18800 and EN 1990 that are used to create load groups and load combinations. Also included in this chapter is the possibility to reduce the generated load groups by examining RFEM results.

- **Chapter 3: Working with RF-COMBI**
  This chapter explains how to select the design situations, to import load cases from RFEM, and how to allocate load cases to actions and actions to action categories. Furthermore, this chapter includes the handling of user-defined safety and combination coefficients, the presentation of the results, and the export of the generated load groups and load combinations to RFEM.

- **Kapitel 4: Examples**
  This chapter includes some examples for reference.

1.4   Installation

The add-on module RF-COMBI is not a separate program but an integrated modul of RFEM. Therefore, the standard installation routine of RFEM has to be started after the purchase of RF-COMBI. Please make sure the new authorization disk is used during the installation as the file on this disk determines which modules are to be activated. The installation process is described in detail in the RFEM manual.

2. Theoretical Background

2.1 General

Especially when applying the new standards DIN 1055-100 [1] and EN 1990 [3], it can be very laborious to consider all potential load situations and to select the decisive one. The add-on module RF-COMBI automatically compiles all possible load groups or load combinations according to the selected standard.

The load cases that have been defined in RFEM provide the basis for RF-COMBI. When importing these load cases, RF-COMBI distinguishes between two categories: genuine load cases and imperfection-type load cases. It is irrelevant for RF-COMBI whether the load cases of the first category are labeled as permanent, variable, accidental, prestress or favorable.

The standards define rules for the combinations of independent actions in various design situations. According to [4], an independent action is given if they result in characteristic values of forces or deformations (e.g. self-weight, live loads, snow and ice loads, wind loads or temperature actions). Actions are independent of one another if they originate from different sources and if their correlation can be neglected with respect to the reliability of the structure.

In RF-COMBI, **actions** are defined. To these actions, RFEM load cases can be allocated. The actions are then assigned to the **action categories** of the selected standard.

2.2 Standards

2.2.1 DIN 1055-100

DIN 1055-100 [1] requires ultimate limit state design and serviceability limit state design.

Ultimate limit states include

- the loss of static equlibrium of the structure or any part of it,
- the failure of the structure or structural members, e.g. due to collapse, excessive deformation, formation of a kinematic chain, loss of stability or gliding,
- the failure of the structure or structural members due to material fatigue or other time-dependent effects.

The ultimate limit states have to be analyzed for the following four design situations:

- Permanent situations which represent the common use of the structure
- Temporary situations which refer to momentary conditions of the structure, e.g. construction level or repair

  Combination rule for permanent and temporary situations (basic combination):

  $$\sum_{j \geq 1} \gamma_{G,j} \cdot G_{k,j} + \gamma_P \cdot P_k + \gamma_{Q,1} \cdot Q_{k,1} + \sum_{i > 1} \gamma_{Q,i} \cdot \psi_{0,i} \cdot Q_{k,i}$$

  Equation 2.1

- Accidental situations which comprehend exceptional actions, e.g. fire, explosion or impact
  Combination rule for accidental situations:

$$\sum_{j\geq1}\gamma_{GA,j}\cdot G_{k,j}+\gamma_{PA}\cdot P_k+A_d+\psi_{1,1}\cdot Q_{k,1}+\sum_{i>1}\psi_{2,i}\cdot Q_{k,i}$$

Equation 2.2

- Seismic situations
  Combination rule for seismic situations:

$$\sum_{j\geq1}G_{k,j}+P_k+\gamma_1\cdot A_{Ed}+\sum_{i\geq1}\psi_{2,i}\cdot Q_{k,i}$$

Equation 2.3

The symbols in these equations are:

$+$	in combination with
Σ	combination of independent actions due to
$G_{k,j}$	independent permanent action consisting of one or more characteristic values of permanent forces or deformation parameters
P_k	independent action due to prestress (characteristic value)
$Q_{k,1}$	prevailing independent variable action consisting of one or more characteristic values of variable forces or deformation parameters
$Q_{k,i}$	remaining independent variable action consisting of one or more characteristic values of variable forces or deformation parameters
A_d	design value of an accidental action
A_{Ed}	design value of a seismic action
$\gamma_{G,j}$	partial safety coefficient of an independent permanent action $G_{k,j}$
$\gamma_{GA,j}$	same as $\gamma_{G,j}$, applicable to accidental design situations
γ_P	partial safety coefficient of an independent permanent action due to prestress
γ_{PA}	same as γ_P, applicable to accidental design situations
$\gamma_{Q,1}$	partial safety coefficient of the prevailing independent variable action $Q_{k,1}$
$\gamma_{Q,i}$	partial safety coefficient of a remaining independent variable action $Q_{k,i}$
γ_I	partial safety coefficient of seismic actions
Ψ	combination factor to determine the representative values of variable actions

The serviceability limit states have to be analyzed for the following three design situations:

- Rare situations with irreversible (lasting) effects on the structure
  Combination rule for rare situations:

$$\sum_{j\geq1}G_{k,j}+P_k+Q_{k,1}+\sum_{i>1}\psi_{0,i}\cdot Q_{k,i}$$

Equation 2.4

- Frequent situations with reversible (non-lasting) effects on the structure
  Combination rule for frequent situations:

$$\sum_{j\geq1}G_{k,j}+P_k+\psi_{1,1}\cdot Q_{k,1}+\sum_{i>1}\psi_{2,i}\cdot Q_{k,i}$$

Equation 2.5

- Quasi-permanent situations with long-term effects on the structure
  Combination rule for quasi-permanent situations:

$$\sum_{j\geq 1} G_{k,j} + P_k + \sum_{i\geq 1} \psi_{2,i} \cdot Q_{k,i}$$

Equation 2.6

The symbols in these equations are analogous as above.

2.2.2 DIN 18800

DIN 18800 [2] requires ultimate limit state design and serviceability limit state design.

The ultimate limit states have to be analyzed for two design situations – basic combinations and accidental combinations. The following combination rules are significant:

Basic combinations:

- Permanent actions G and all unfavorable variable actions Q_i
  Combination rule:

$$\sum_{j\geq 1} \gamma_{G,j} \cdot G_{k,j} + \sum_{i>1} \gamma_{Q,i} \cdot \psi \cdot Q_{k,i}$$

Equation 2.7

- Permanent actions G and one unfavorable variable action Q_i in each case
  Combination rule:

$$\sum_{j\geq 1} \gamma_{G,j} \cdot G_{k,j} + \gamma_{Q,i} \cdot Q_{k,i}$$

Equation 2.8

Accidental combinations:

- Permanent actions G, all unfavorable variable actions Q_i and one accidental action A
  Combination rule:

$$\sum_{j\geq 1} \gamma_{GA,j} \cdot G_{k,j} + \sum_{i>1} \gamma_{QA,i} \cdot \psi \cdot Q_{k,i} + \gamma_{A,i} \cdot A_{k,i}$$

Equation 2.9

The symbols in these equations are:

$G_{k,j}$ independent permanent action consisting of one or more characteristic values of permanent forces or deformation parameters

$Q_{k,i}$ independent variable action consisting of one or more characteristic values of variable forces or deformation parameters

$A_{k,i}$ independent accidental action consisting of one or more characteristic values of variable forces or deformation parameters

$\gamma_{G,j}$ partial safety coefficient of an independent permanent action $G_{k,j}$

$\gamma_{Q,j}$ partial safety coefficient of an independent variable action $Q_{k,1}$

$\gamma_{A,i}$ partial safety coefficient of an independent accidental action $A_{k,i}$

$\gamma_{GA,j}$ same as $\gamma_{G,j}$, applicable to accidental design situations

ψ combination factor to determine the representative values of variable actions

2.2.3   EN 1990

EN 1990 [3] makes a destinction between ultimate limit states and serviceability limit states.

Ultimate limit states include:

- **EQU**: Loss of static equilibrium of the structure or any part of it, where
  - minor variations in the value or the spatial distribution of action from a single source are significant and
  - the strengths of construction materials or ground are generally not governing.
- **STR**: The internal failure or excessive deformation of the structure or structural members, including footings, piles, basing walls, etc., where the strength of the construction materials governs.
- **GEO**: The failure or excessive deformation of the ground where the strength of soil or rock are significant in providing resistance.
- **FAT**: The fatigue failure of the structure or structural members.

The ultimate limit states have to be analyzed for the following four design situations:

- Permanent situations which represent the common use of the structure
- Temporary situations which refer to momentary conditions of the structure, e.g. construction level or repair

  The combination rule for permanent and temporary situations (basic combination) is either

  $$\sum_{j\geq 1}\gamma_{G,j}\cdot G_{k,j} + \gamma_P \cdot P_k + \gamma_{Q,1}\cdot Q_{k,1} + \sum_{i>1}\gamma_{Q,i}\cdot \psi_{0,i}\cdot Q_{k,i}$$

  Equation 2.10

  or, alternatively for the ultimate limit states STR and GEO, the more unfavorable combination according to equation 2.11 or equation 2.12.

  $$\sum_{j\geq 1}\gamma_{G,j}\cdot G_{k,j} + \gamma_P \cdot P_k + \gamma_{Q,1}\cdot \psi_{0,1}\cdot Q_{k,1} + \sum_{i>1}\gamma_{Q,i}\cdot \psi_{0,i}\cdot Q_{k,i}$$

  Equation 2.11

  $$\sum_{j\geq 1}\xi_j \cdot \gamma_{G,j}\cdot G_{k,j} + \gamma_P \cdot P_k + \gamma_{Q,1}\cdot Q_{k,1} + \sum_{i>1}\gamma_{Q,i}\cdot \psi_{0,i}\cdot Q_{k,i}$$

  Equation 2.12

- Accidental situations which comprehend exceptional actions, e.g. fire, explosion or impact

  Combination rule for accidental situations:

  $$\sum_{j\geq 1}G_{k,j} + P + A_d + (\psi_{1,1}\text{or}\psi_{2,1})\cdot Q_{k,1} + \sum_{i>1}\psi_{2,i}\cdot Q_{k,i}$$

  Equation 2.13

- Seismic situations
  Combination rule for seismic situations:

  $$\sum_{j\geq 1}G_{k,j} + P_k + A_{Ed} + \sum_{i\geq 1}\psi_{2,i}\cdot Q_{k,i}$$

  Equation 2.14

The symbols in these equations are analogous to DIN 1055-100, cf. chapter 2.2.1. In equation 2.12, ξ_i is the reduction factor of the permanent unfavorable actions.

The serviceability limit states have to be analyzed for the following three design situations:

- Rare situations with irreversible (lasting) effects on the structure
  Combination rule for rare situations:

$$\sum_{j \geq 1} G_{k,j} + P_k + Q_{k,1} + \sum_{i > 1} \psi_{0,i} \cdot Q_{k,i}$$

Equation 2.15

- Frequent situations with reversible (non-lasting) effects on the structure
  Combination rule for frequent situations:

$$\sum_{j \geq 1} G_{k,j} + P_k + \psi_{1,1} \cdot Q_{k,1} + \sum_{i > 1} \psi_{2,i} \cdot Q_{k,i}$$

Equation 2.16

- Quasi-permanent situations with long-term effects on the structure
  Combination rule for quasi-permanent situations:

$$\sum_{j \geq 1} G_{k,j} + P_k + \sum_{i \geq 1} \psi_{2,i} \cdot Q_{k,i}$$

Equation 2.17

The combination rules are set in the European standard EN 1990, but the individual countries are able to modify the values of the coefficients. When selecting "EN 1990 CEN" in RF-COMBI, the coefficients according to the European committee CEN are applied. Option "EN 1990 CZ" is based on the national Czech coefficients.

2.3   Reducing the Generated Load Groups

The number of generated load groups or load combinations significantly depends on the complexity of the structure and on the quantity of actions and load cases.

RF-COMBI provides an option to effectively reduce the number of load groups by generating only the governing ones. For this purpose, one or more load combinations are generated automatically and analyzed with RFEM. The number of load combinations depends on the selected design situations.

At every FE node, the results are examined for extremal values load case by load case. Only the relevant load cases are then used in RF-COMBI when generating load groups or load combinations.

The reduction via automatically generated load combinations guarantees that the results of RF-COMBI include all governing load groups. When preferred, user-defined load combinations can be created in RFEM and also be used in RF-COMBI to reduce the number of generated load groups.

This reduction is only possible for generating load groups, i.e. not for load combinations.

3. Working with RF-COMBI

3.1 Starting RF-COMBI

RF-COMBI is called up either via menu *Additional Modules* → *Others* → *RF-COMBI* or via the relevant entry among the additional modules of the *Data* navigator.
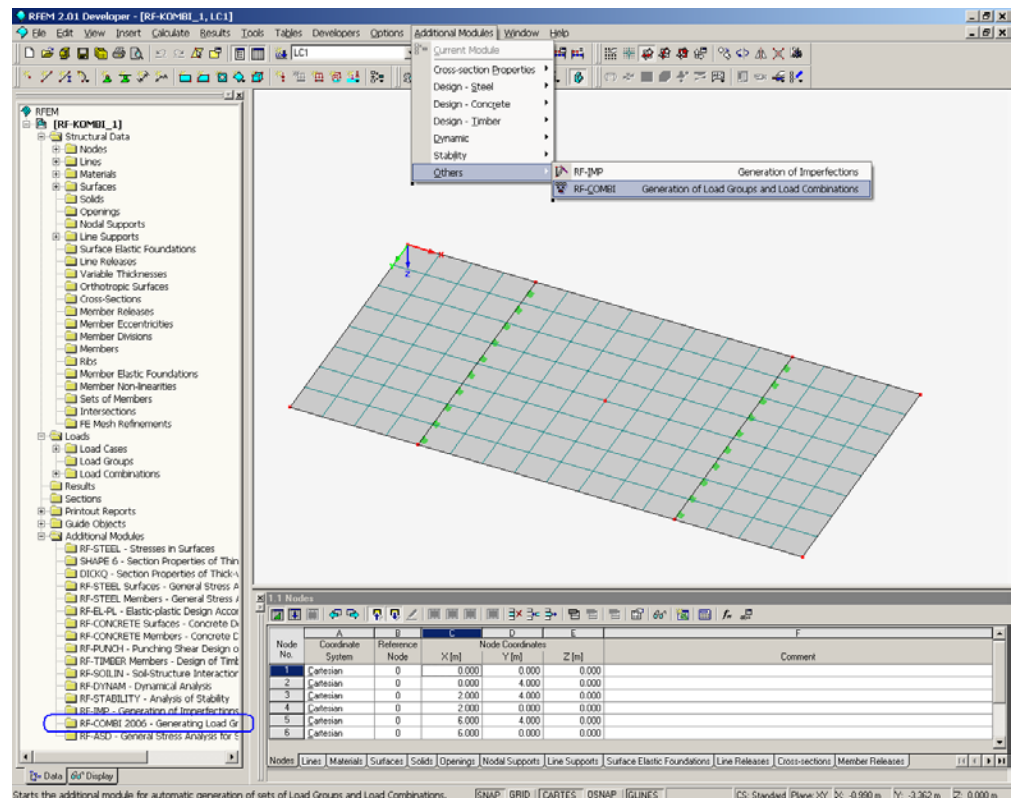

Figure 3.1: Calling up RF-COMBI via menu *Additional Modules* or the *Data Navigator*

3.2 Masks

Both the input to define the RF-COMBI cases and the numerical results on the screen are handled in masks.

On the left, the navigator lists all available masks. The list box of all RF-COMBI cases is arranged above it.

The masks can be accessed by either clicking on the entry in the navigator or browsing through entries via the [F2] and [F3] keys or the [<] and [>] buttons.

[Calculation] starts the generation when the input of data has been completed.

[OK] saves all RF-COMBI data before quitting the module, [Cancel] terminates it without saving any data.

[Help] or the [F1] key call up the online help.

[Coefficients...] calls up the dialog to check or edit the partial safety and combination coefficients.

[Check] performs a plausibility check.

Buttons [Calculation], [Coefficients...] and [Check] are only available in the input masks.

In the result masks, button [Export...] is accessible to transfer the generated load groups or load combinations to RFEM.
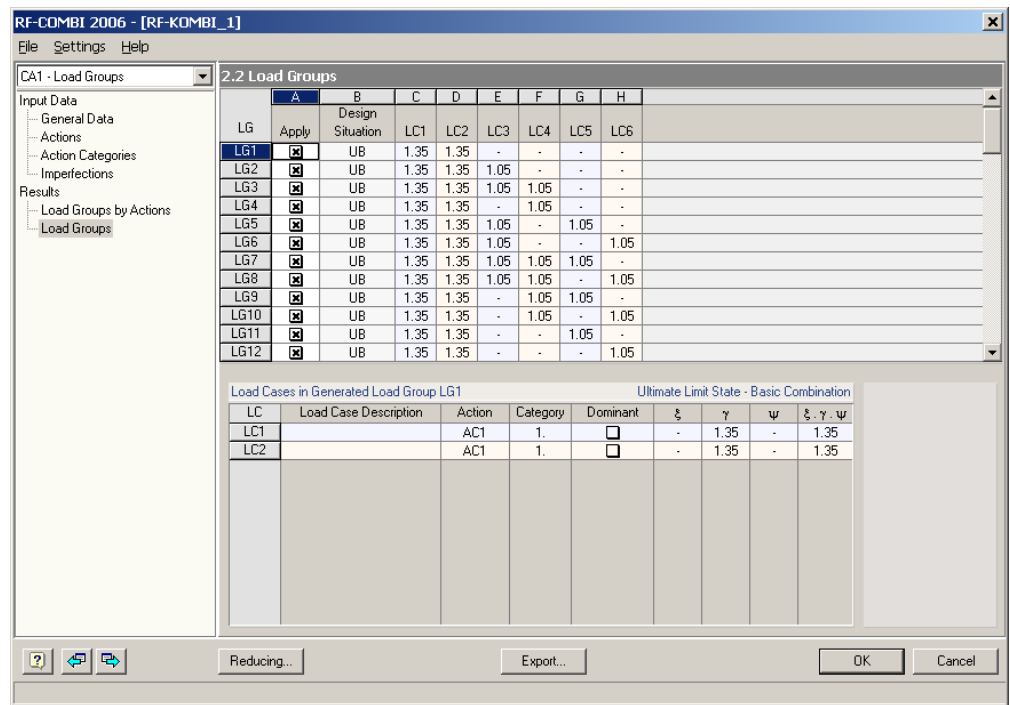

Figure 3.2: Results mask 2.2 *Load Groups*

3.3 Input Masks

All required data and parameters are defined in input masks.

3.3.1 Combination Rules according to DIN 1055-100

3.3.1.1 Mask 1.1 General Data

When RF-COMBI is called up, mask 1.1 *General Data* appears.
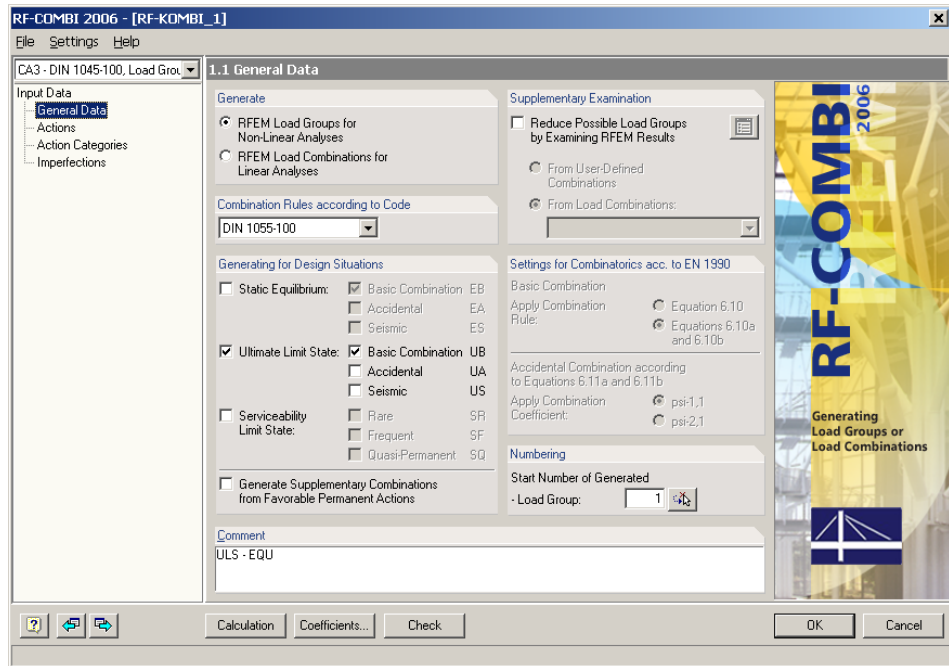
Figure 3.3: Mask 1.1 *General Data*

Section *Generate* determines whether *load groups for non-linear analyses* or *load combinations for linear analyses* are to be generated. The difference between load groups and load combinations is described in detail in the RFEM manual.

In section *Combination rules according to code*, the standard can be selected that controls the generation of the load groups or load combinations. *DIN 1055-100*, *DIN 18800* and *EN 1990* are available. This chapter 3.3.1.1 refers to DIN 1055-100.

DIN 1055-100 requires ultimate limit state design and serviceability limit state design. Ultimate limit state design distinguishes between the loss of static equilibrium and failure of the structure. The specifications are set in section *Generating for Design Situations*:

- Static equilibrium (position stability in ultimate limit state, partial safety coefficients of design criterion loss of static equilibrium)

  - Basic combination – according to equation 2.1
  - Accidental – according to equation 2.2
  - Seismic – according to equation 2.3

- Ultimate limit state (failure of the structure, partial safety coefficients of design criterion collapse of the structure)

  - Basic combination – according to equation 2.1
  - Accidental – according to equation 2.2
  - Seismic – according to equation 2.3

- Serviceability limit state (service requirements)

  - Rare – according to equation 2.4
  - Frequent – according to equation 2.5
  - Quasi-permanent – according to equation 2.6

Option *Generate supplementary combinations from favorable permanent actions* is to distinguish between favorable and unfavorable permanent actions so that different partial safety coefficients are considered, which only applies to the ultimate limit state design situations. The static equilibrium design situations automatically account for the influence of favorable and unfavorable permanent actions, while the serviceability limit state design situations do not differentiate between favorable and unfavorable actions.

In dialog section *Supplementary Examination*, it can be determined whether to *reduce the possible load groups by examining RFEM results*. Via the button next to this option, it is possible to limit the result values that are relevant for this analysis.
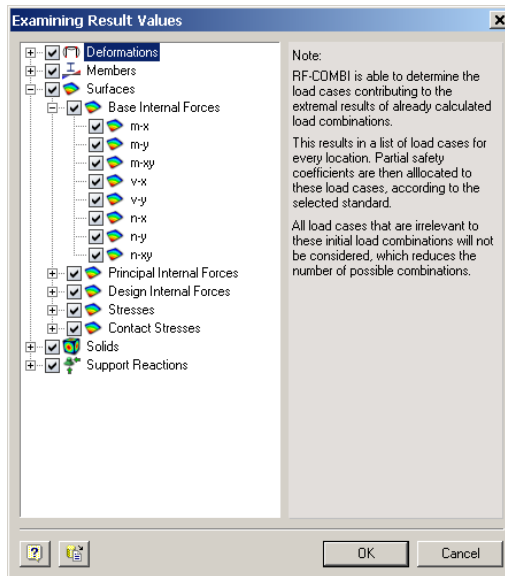

Figure 3.4: Dialog *Examining Result Values*

Either automatically generated combinations can be analyzed in RFEM or previously defined RFEM combinations can be selected. The reduction of results is explained in chapter 2.3.

In dialog section *Numbering*, the *first number of generated load group* or *load combination* can be specified that will be created in RFEM after the export. By clicking on the button right to the input field, the first vacant number is preset.

3.3.1.2 Mask 1.2 Load Cases in Actions

In this mask, actions are defined. The existing RFEM load cases are then allocated to these actions. The mask comprises sections *Actions*, *Existing Load Cases* and *Load Cases in Action*.
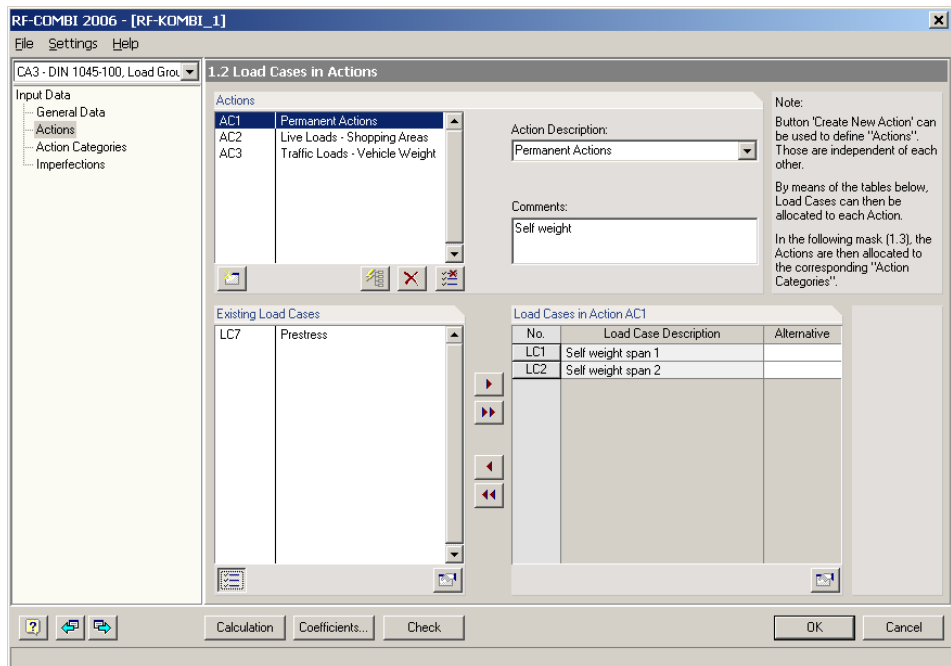
Figure 3.5: Mask 1.2 *Load Cases in Actions*

Section *Actions* lists all actions that have been defined. It is possible to add an *Action Description* or a *Comment*.

A new action is created by clicking on the left button at the bottom of section *Actions*.

The second button creates as many new actions as existing load cases. Every load case is allocated to exactly one action.

The third button deletes the selected action.

The right button of section *Actions* deletes all actions that have been created.

When opening this mask, section *Existing Load Cases* lists all load cases that have been defined in RFEM. This means that they are not allocated to any action yet. Load cases that have been defined as imperfections in RFEM are not included in this list.

If the button at the bottom left of this section is pressed (i.e. active), then the load cases which have not been allocated yet are listed. If the button is not pressed (i.e. inactive), all existing load cases are listed.

The second button at the bottom of this section calls up the general data of the selected load case for modification.

Section *Load Cases in Action* lists all load cases that have been assigned to the selected action. The load cases can be allocated by clicking on the arrow buttons between sections *Existing Load Cases* and *Load Cases in Action AC*. It is possible to transfer either only the selected load case(s) or all existing load cases at once. Every load case can be allocated only once, i.e. to only one action. The button at the bottom of this section calls up the general data of the selected load case for modification.

It is possible to include two or more load cases as *alternative* ones. This means that these load cases never simultaneously appear in a load group or load combination. Load cases can be labeled as alternative ones by an identical name in column *Alternative*.
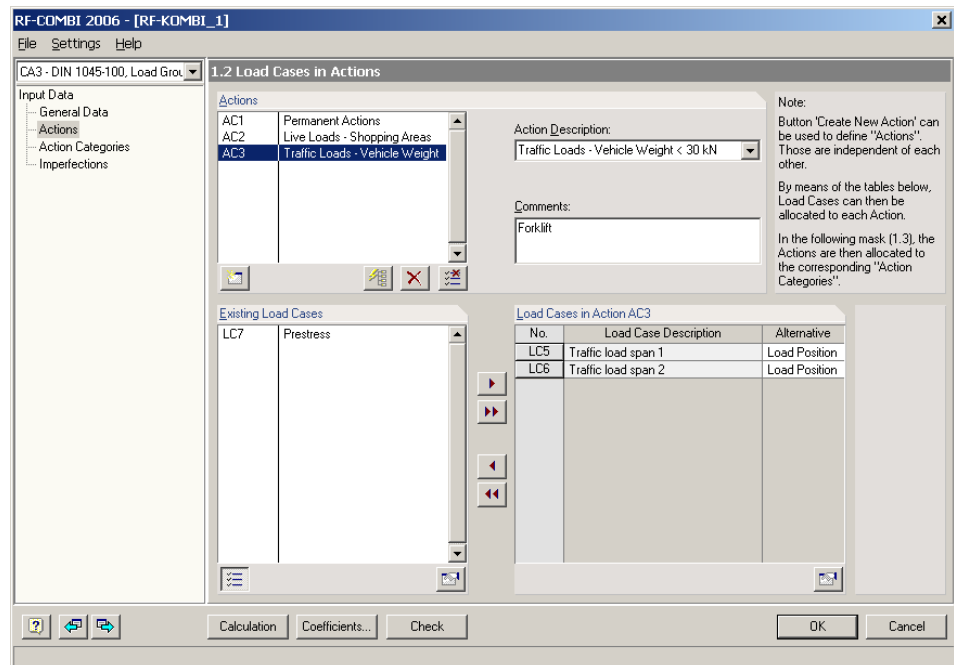

Figure 3.6: Alternative load cases LC5 and LC6

3.3.1.3 Mask 1.3 Actions in Action Categories

Here, the actions *AC* of the previous mask are allocated to action categories.
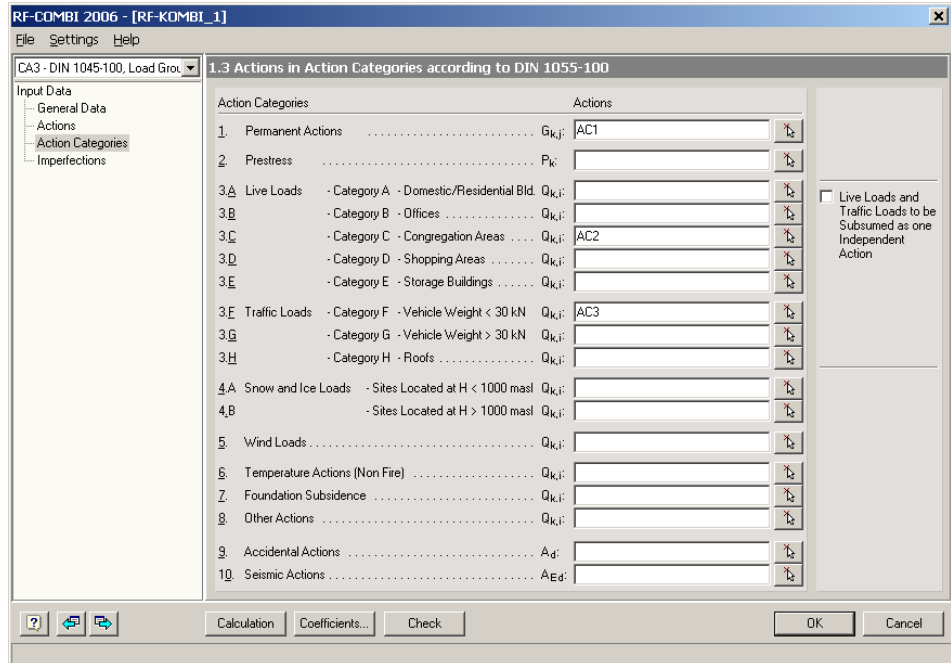

Figure 3.7: Mask 1.3 *Actions in Action Categories*

The actions are assigned in the *Actions* input fields that are supported by the pick buttons: Dialog *Select Actions* is called up which lists all actions that have not been allocated yet.
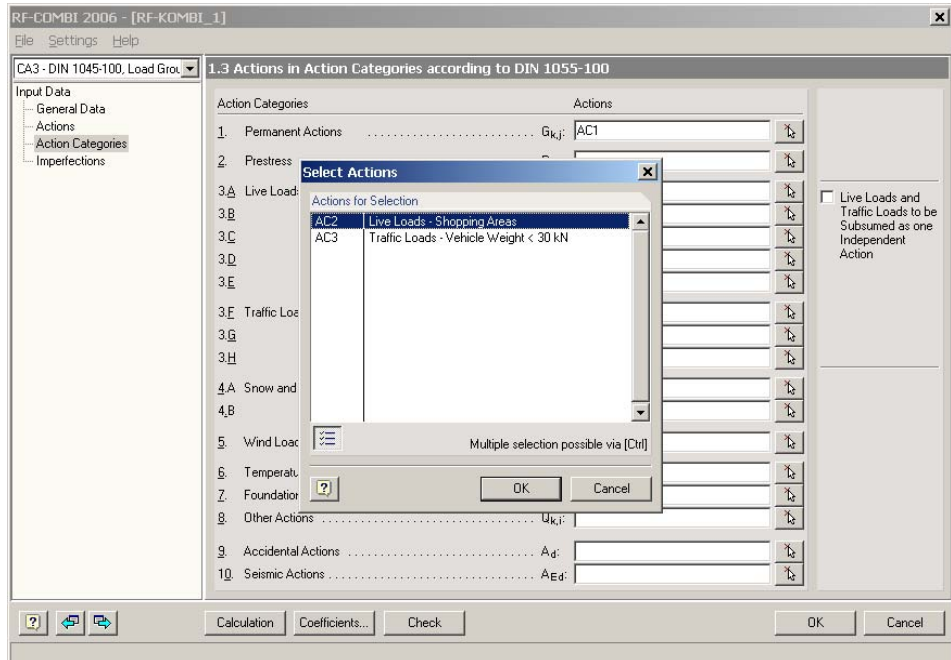

Figure 3.8: Dialog *Select Actions*

In this mask, option *Subsume Live Loads and Traffic Loads to be Subsumed as one Independent Action* is available. The possibility to include live loads and traffic loads of a building within one independent action is described e.g. in [4], appendix A, page 37. This option has an effect on the generation of load groups or load combinations according to

equations 2.1, 2.2, 2.4 and 2.5, where the dominant variable action $Q_{k,1}$ is used. If this option is active, then all live loads and traffic loads are either simultaneously considered as the dominant action, or none of them is regarded as dominant. This means that all live loads and traffic loads are consistently multiplied by the same combination coefficient ψ.

3.3.1.4 Mask 1.4 Imperfection-Type Load Cases

Mask *1.4 Imperfection-Type Load Cases* is available when load groups are to be generated. Imperfections require 2nd or 3rd order analyses.

This mask consists of sections *Existing Load Cases - Type 'Imperfection'*, *Imperfection-Type Load Cases in Combinatorics* and *Options*.
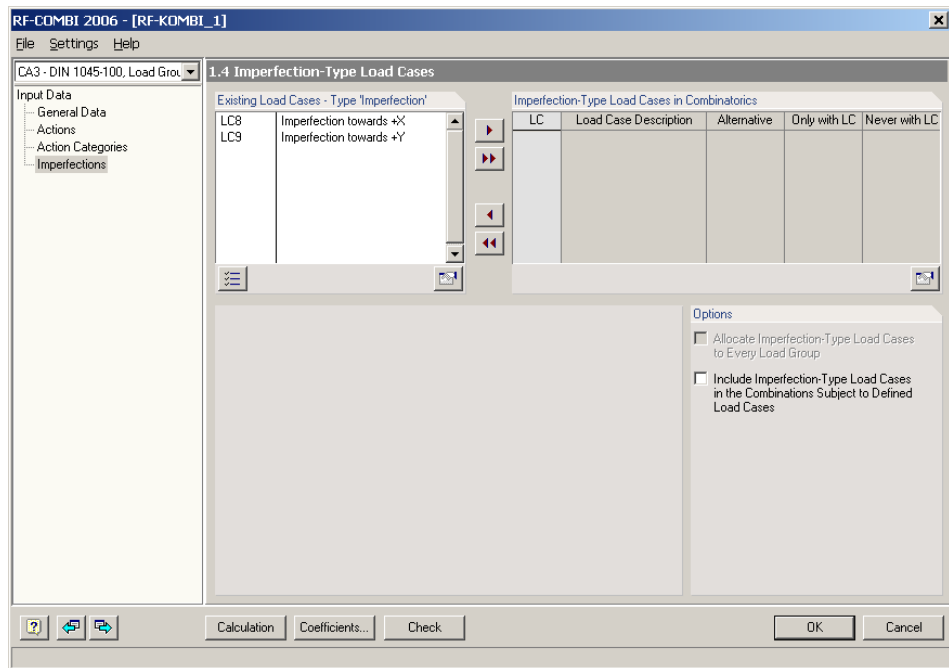
Figure 3.9: Mask 1.4 *Imperfection-Type Load Cases*

Section *Existing Load Cases - Type 'Imperfection'* lists all load cases that have been labeled as imperfections in RFEM. These load cases can be included in the combinatorics via the arrow buttons between sections *Existing Load Cases Cases - Type 'Imperfection'* and *Imperfection-Type Load Cases in Combinatorics*.

RF-COMBI considers only those imperfection-type load cases that are listed in section *Imperfection-Type Load Cases in Combinatorics*.

As soon as at least one imperfection-type load case has been selected, every possible load group is created twofold – with and without imperfections. If only load groups with imperfections are to be generated, option *Allocate Imperfection-Type Load Cases to Every Load Group* must be set active in section *Options*.

In figure 3.10, load cases LC8 and LC9 have been selected. With these settings, all load groups are created without imperfections first. Then, LC8 is included in the generation of further load groups, followed by an extra run with LC9 instead. Finally, LC8 and LC9 are applied simultaneously.
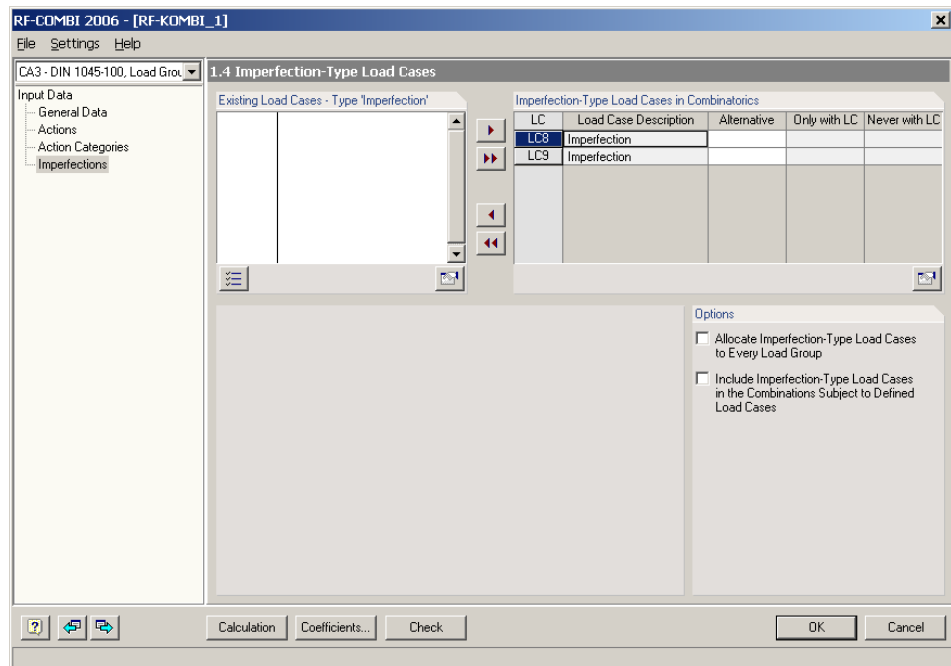
Figure 3.10: Mask 1.4 *Imperfection-Type Load Cases in Combinatorics*

It is also possible to classify *Alternative* imperfection-type load cases. Then only one imperfection is added per load group, i.e. they are not applied simultaneously.

Columns *Only with LC* and *Never with LC* provide the possibility to additionally reduce the number of generated load groups. For this purpose, option *Include Imperfection-Type Load Cases in the Combination Subject to Defined Load Cases* must be set active. Then the correlation can be specified between an imperfection and a 'genuine' load case.
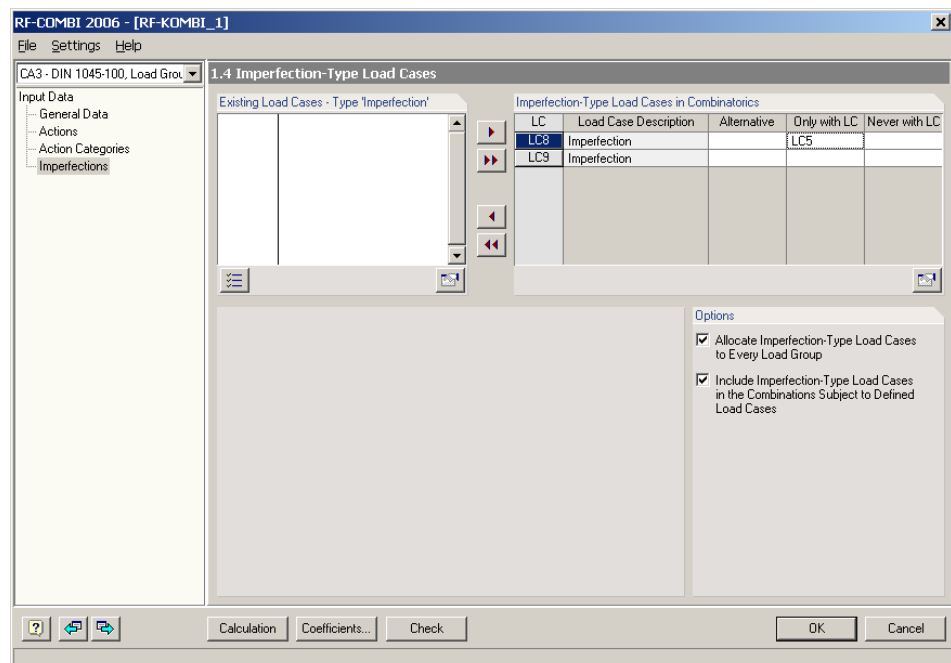
Figure 3.11: Mask 1.4 *Imperfection-Type Load Cases*, Option *Only with LC*

3.3.1.5 Dialog Coefficients

Dialog *Coefficients* is called up via button [Coefficients...]. There are two registers available that contain the default settings of the *Partial Safety Coefficients* and the *Combination Coefficients* according to DIN 1055-100. These factors are applied when load groups or load combinations are generated.

Register *Partial Safety Coefficients* includes both design situations *Static Equilibrium* and *Ultimate Limit State*. The relevant partial safety coefficients are different, though.
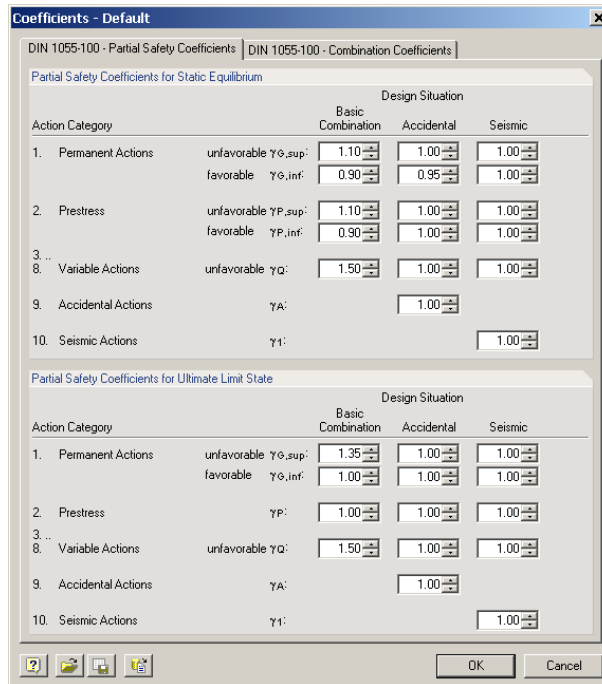
Figure 3.12: Default Partial Safety Coefficients according to DIN 1055-100

The factors in register *Combination Coefficients* are dependent on the action categories.
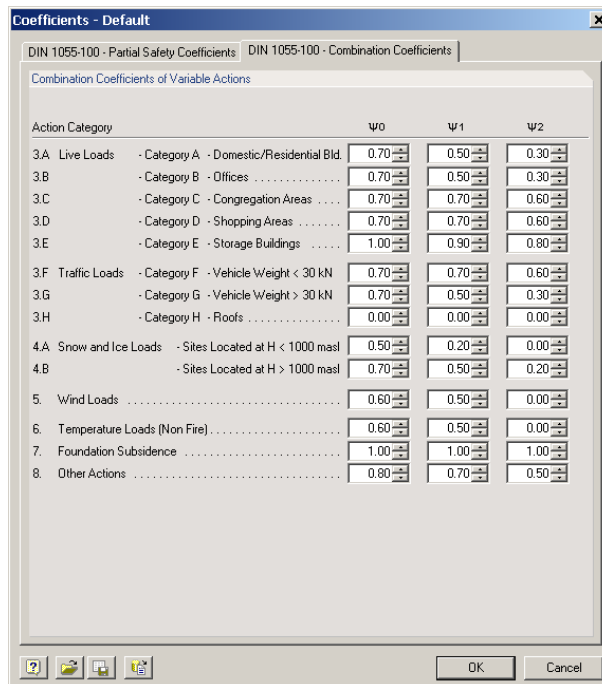
Figure 3.13: Default Combination Coefficients according to DIN 1055-100

Apart from these default values according to the selected code, user-defined sets of coefficients can be created and saved for further use. Button [Save Coefficients] calls up the dialog to define a name for a user-defined set of coefficients.
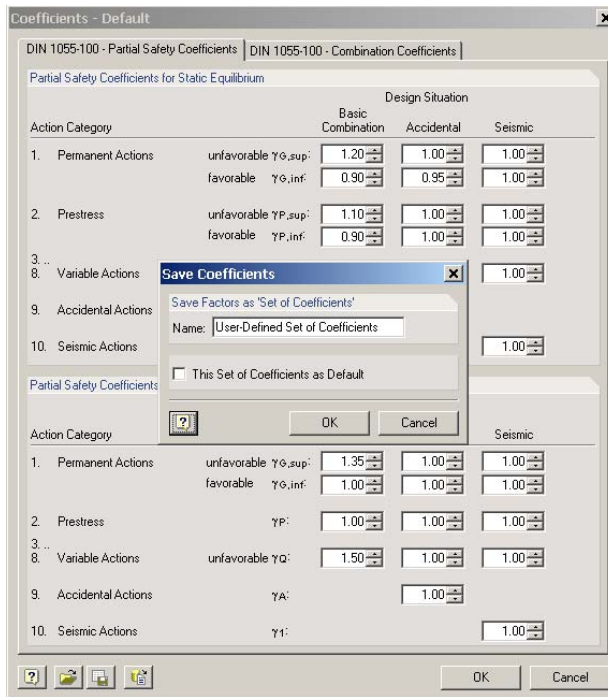
Figure 3.14: Dialog *Save Coefficients*

This set of coefficients can be set as default.

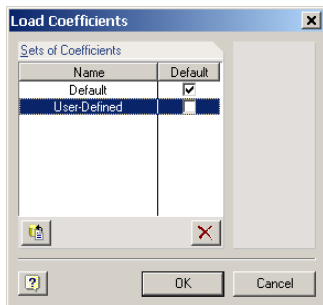Button [Load Set of Coefficients] calls up the dialog to import a specific user-defined set of coefficients.

Figure 3.15: Dialog *Load Coefficients*

In column *Name*, the table is headed by the *Default* set of coefficients according to the selected standard. This set can neither be modified nor deleted.

In the column right to it, it is possible to choose a different set of coefficients as default.

3.3.2 Combination Rules according to DIN 18800

3.3.2.1 Mask 1.1 General Data

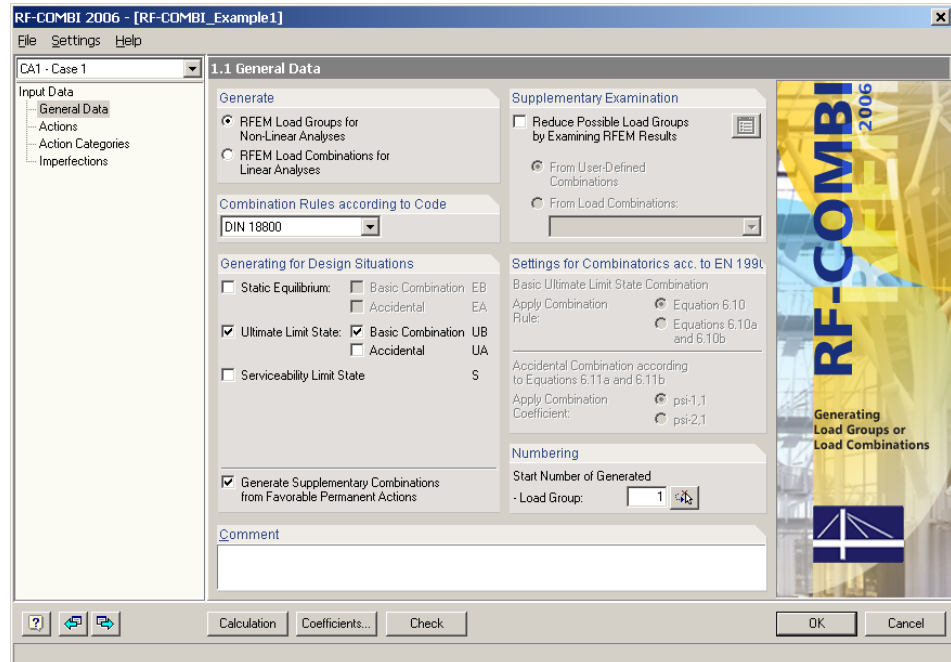When RF-COMBI is called up, mask 1.1 *General Data* appears.

Figure 3.16: Mask 1.1 *General Data*

This mask is identical to the one which is described in chapter 3.3.1.1 (p. 12), except for section *Generating for Design Situations*.

DIN 18800 requires ultimate limit state design and serviceability limit state design. Ultimate limit state design distinguishes between the loss of static equilibrium and the failure of the structure. The specifications are set in section *Generating for Design Situations*:

- Static Equilibrium (position stability in ultimate limit state, partial safety coefficients of design criterion loss of static equilibrium)

  - Basic Combination – according to equations 2.7 and 2.8
  - Accidental – according to equation 2.9

- Ultimate Limit State (failure of the structure, partial safety coefficients of design criterion collapse of the structure)

  - Basic Combination – according to equations 2.7 and 2.8
  - Accidental – according to equation 2.9

- Serviceability Limit State (service requirements) – according to equation 2.7

3.3.2.2 Mask 1.2 Actions

In this mask, actions are defined. The existing RFEM load cases can then be allocated to these actions. The functionality which is described in chapter 3.3.1.2 (p. 14) does not depend on a specific standard.
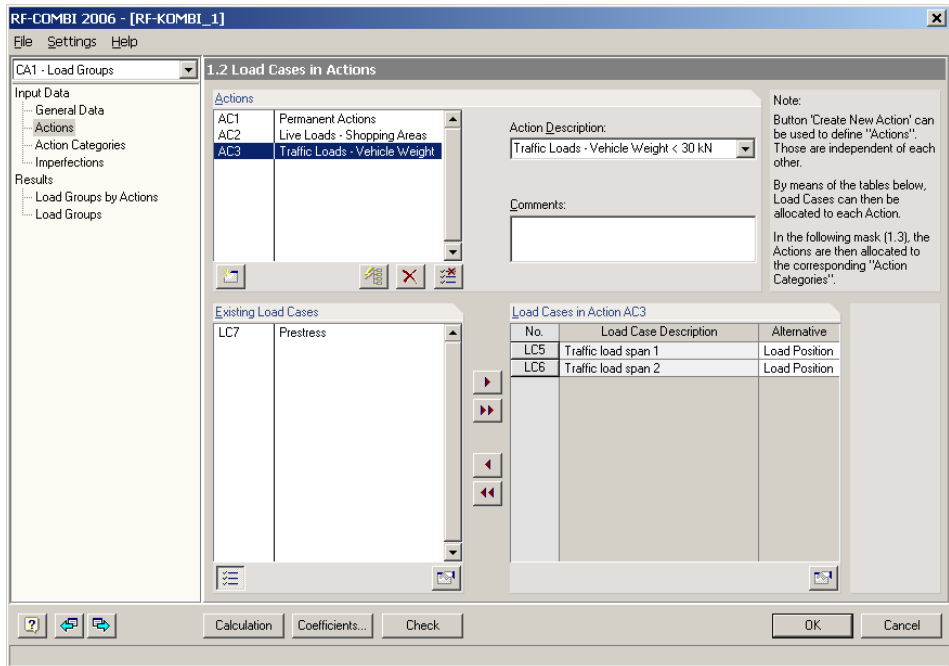
Figure 3.17: Mask 1.2 *Load Cases in Actions*

3.3.2.3 Mask 1.3 Action Categories

Here, the actions *AC* of the previous mask are allocated to action categories. The functionality is described in chapter 3.3.1.3 (p. 16).
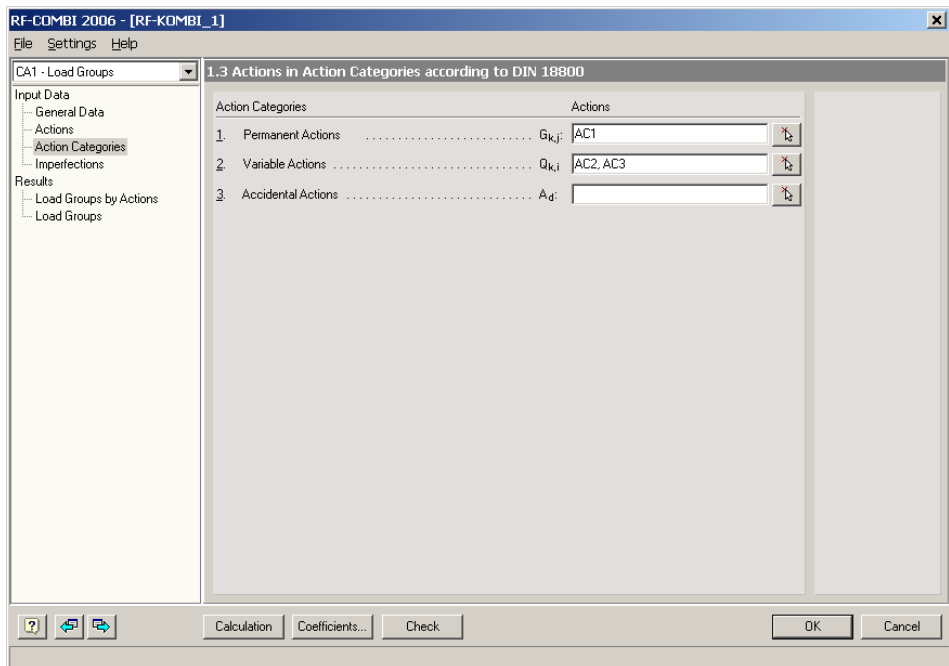

Figure 3.18: Mask 1.3 *Actions in Action Categories*

3.3.2.4 Mask 1.4 Imperfections

Mask *1.4 Imperfection-Type Load Cases* is available when load groups are to be generated. Imperfections require 2nd or 3rd order analyses.

This mask consists of sections *Existing Load Cases - Type 'Imperfection'*, *Imperfection-Type Load Cases in Combinatorics* and *Options*. Its description is in chapter 3.3.1.2 (p. 14).
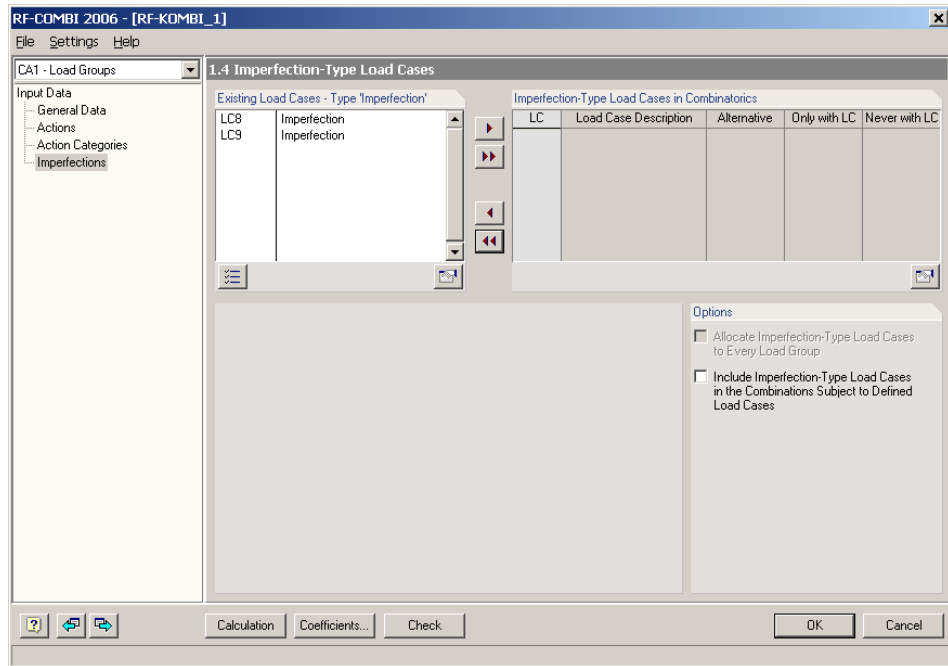
Figure 3.19: Mask 1.4 *Imperfection-Type Load Cases*

3.3.2.5 Dialog Coefficients

Dialog *Coefficients* is called up via button [Coefficients...]. There are two registers available that contain the default settings of the *Partial Safety Coefficients* and the *Combination Coefficients* according to DIN 18800. These factors are applied when load groups or load combinations are generated.

Register *Partial Safety Coefficients* includes the design situations *Static Equilibrium*, *Ultimate Limit State* and *Serviceability Limit State* with the relevant partial safety coefficients.
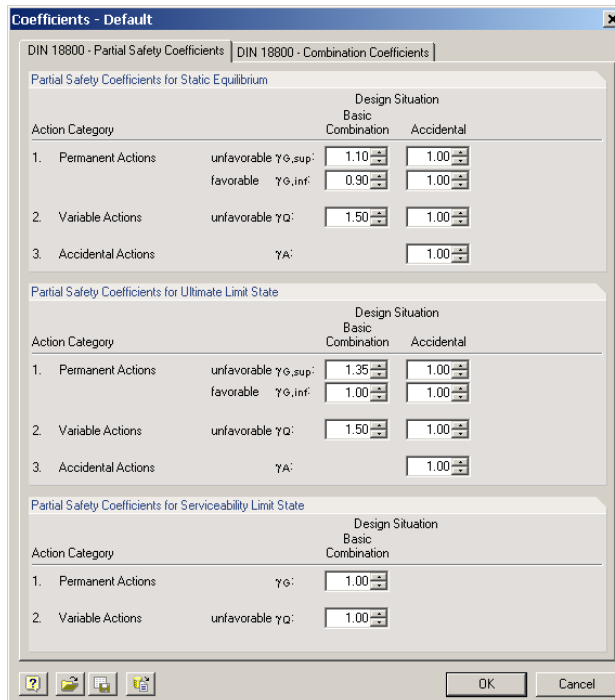
Figure 3.20: Default Partial Safety Coefficients according to DIN 18800

The factors in register *Combination Coefficients* are related to the design situation.
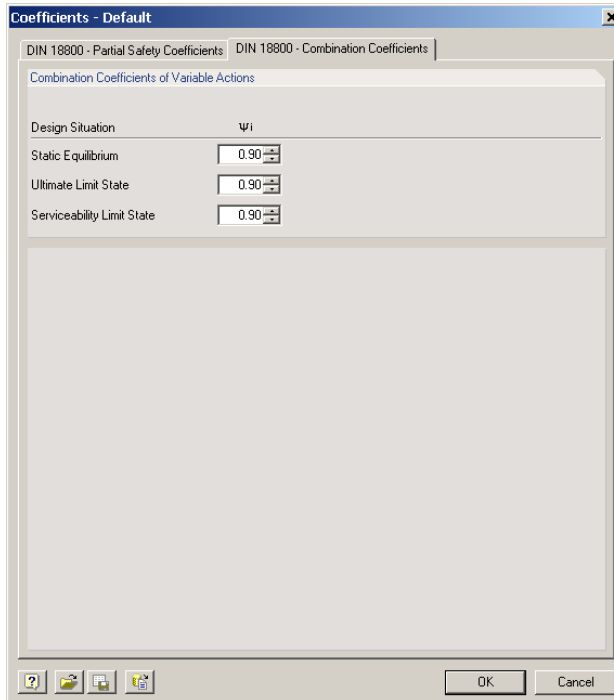

Figure 3.21: Default Combination Coefficients according to DIN 18800

Apart from these default values according to the selected code, user-defined sets of coefficients can be created. This is described in chapter 3.3.1.5 (p. 19).

3.3.3 Combination Rules according to EN 1990

3.3.3.1 Mask 1.1 General Data
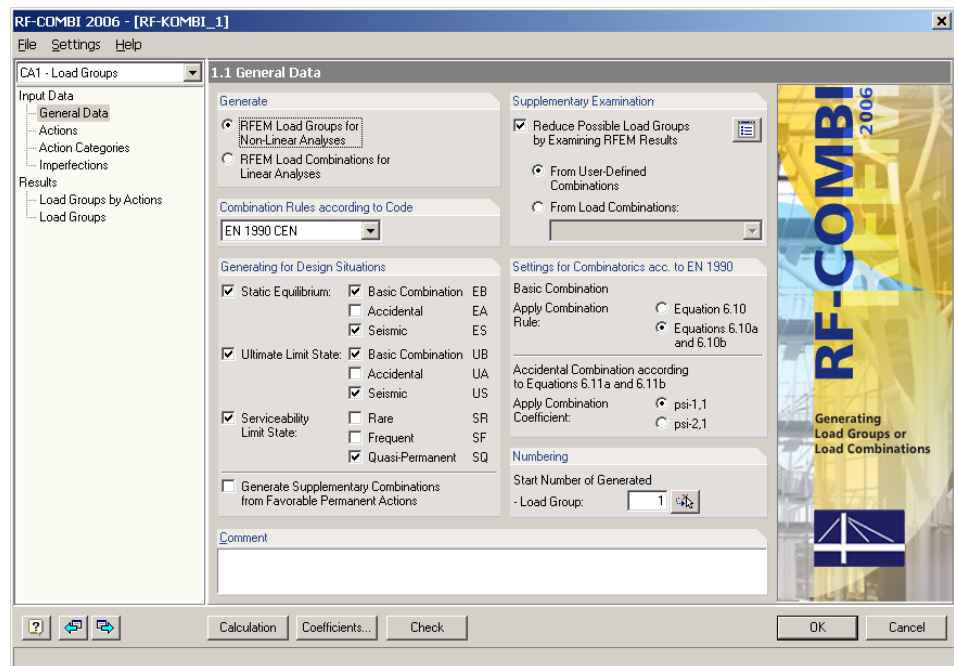
When RF-COMBI is called up, mask *1.1 General Data* appears.

Figure 3.22: Mask 1.1 *General Data*

This mask is identical to the one which is described in chapter 3.3.1.1 (p. 12), except for section *Generating for Design Situations*.

Two variants of EN 1990 are avaible in RF-COMBI – *EN 1990 CEN* and *EN 1990 CZ* – which differ in some default coefficients. The following figures represent the CEN coefficients.

EN 1990 requires ultimate limit state design and serviceability limit state design. Ultimate limit state design distinguishes between the loss of static equilibrium and the failure of the structure. The specifications are set in section *Generating for Design Situations*:

- Static Equilibrium (position stability in ultimate limit state, partial safety coefficients of design criterion loss of static equilibrium)

    - Basic Combination – according to equations 2.10, 2.11 or 2.12
    - Accidental – according to equation 2.13
    - Seismic – according to equation 2.14

- Ultimate Limit State (failure of the structure, partial safety coefficients of design criterion collapse of the structure)

    - Basic Combination – according to equations 2.10, 2.11 or 2.12
    - Accidental – according to equation 2.13
    - Seismic – according to equation 2.14

- Serviceability Limit State (service requirements)

    - Rare – according to equation 2.15
    - Frequent – according to equation 2.16
    - Quasi-permanent – according to equation 2.17

3.3.3.2 Mask 1.2 Actions

In this mask, actions are defined. The existing RFEM load cases can then be allocated to these actions. The functionality which is described in chapter 3.3.1.2 (p. 14) does not depend on a specific standard.
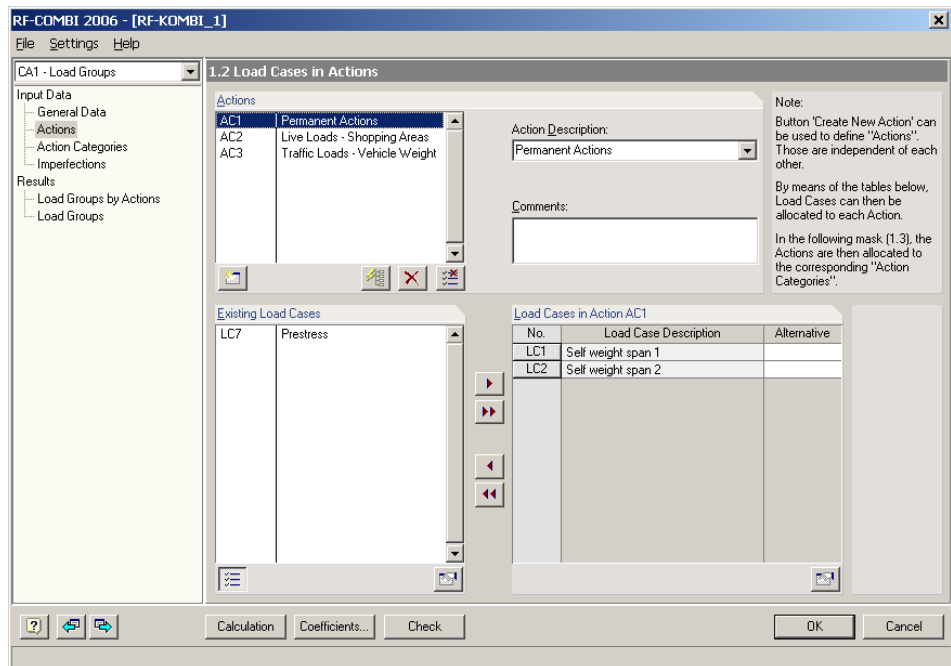

Figure 3.23: Mask 1.2 *Load Cases in Actions*

3.3.3.3 Mask 1.3 Action Categories

Here, the actions *AC* of the previous mask are allocated to action categories. The functionality is described in chapter 3.3.1.3 (p. 16).
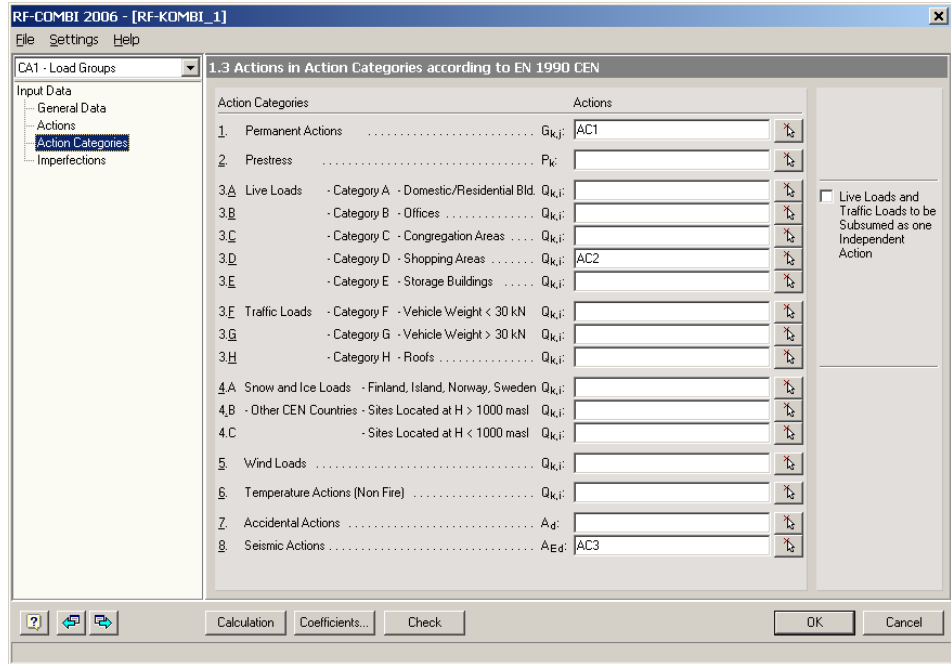

Figure 3.24: Mask 1.3 *Actions in Action Categories*

3.3.3.4 Mask 1.4 Imperfections

Mask *1.4 Imperfection-Type Load Cases* is available when load groups are to be generated. Imperfections require 2nd or 3rd order analyses.

This mask consists of sections *Existing Load Cases - Type 'Imperfection'*, *Imperfection-Type Load Cases in Combinatorics* and *Options*. Its description is in chapter 3.3.1.2 (p. 14).
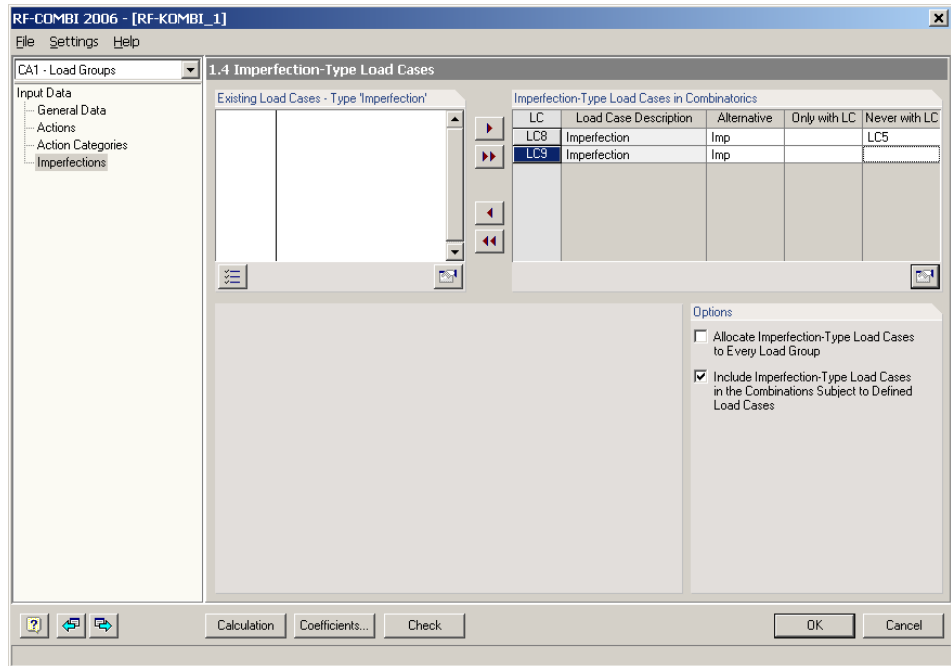

Figure 3.25: Mask 1.4 *Imperfection-Type Load Cases*

3.3.3.5 Dialog Coefficients

Dialog *Coefficients* is called up via button [Coefficients…]. There are two registers that contain the default settings of the *Partial Safety Coefficients* and the *Combination Coefficients* according to EN 1990. These factors are applied when load groups or load combinations are generated.

Register *Partial Safety Coefficients* includes both design situations *Static Equilibrium* and *Ultimate Limit State*. The relevant partial safety coefficients are different, though.
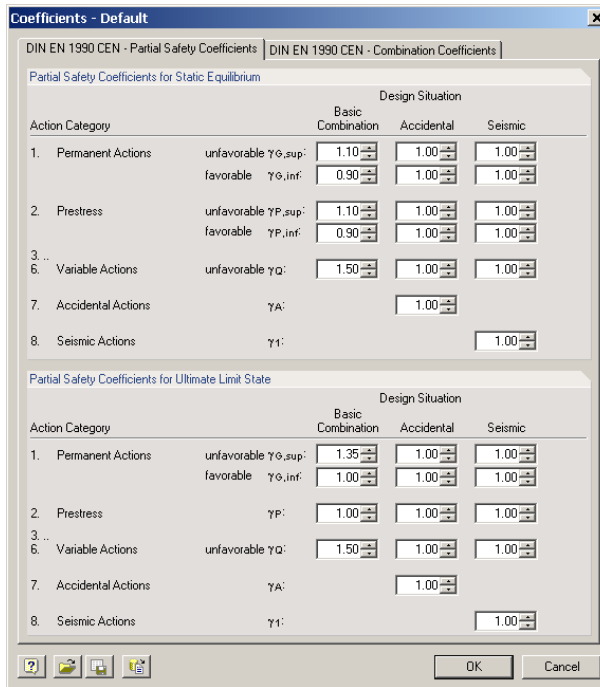
Figure 3.26: Default Partial Safety Coefficients according to EN 1990 CEN

The factors in register *Combination Coefficients* are related to the design situation.
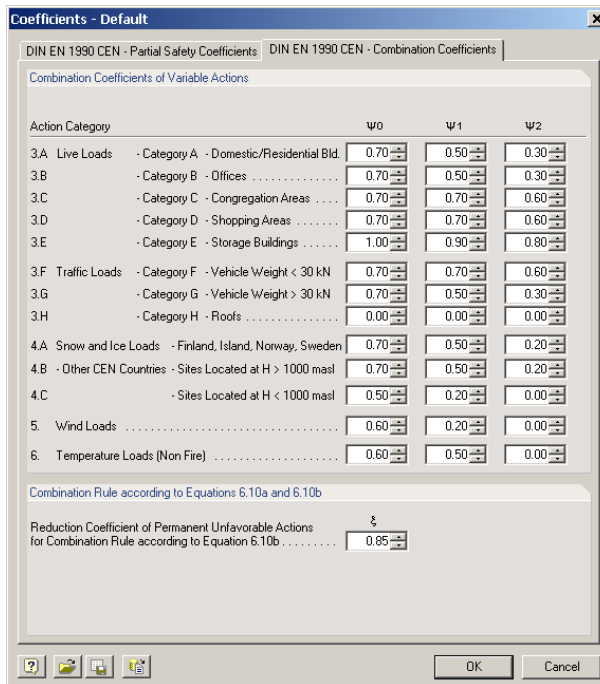

Figure 3.27: Default Combination Coefficients according to EN 1990 CEN

EN 1990 requires the specification of the reduction coefficient ξ which is applied in equation 2.12, i.e. equation 6.10b according to EN 1990.

Apart from these default values according to the selected code, user-defined sets of coefficients can be created. This is described in chapter 3.3.1.5 (p. 19).

3.4   Results Masks

There are two results masks in RF-COMBI. In the first one, the generated results are listed by actions. This clearly arranged presentation corresponds to the manner of definition within the standard. In the second results mask, all load groups or load combinations are listed separately with the relevant load cases.

3.4.1   Generated Load Groups

3.4.1.1 Mask 2.1 Load Groups by Actions

Mask *2.1 Load Groups by Actions* consists of two parts. In the upper part, the generated load groups are generally listed by actions. The details of the selected line are specified in the part below.
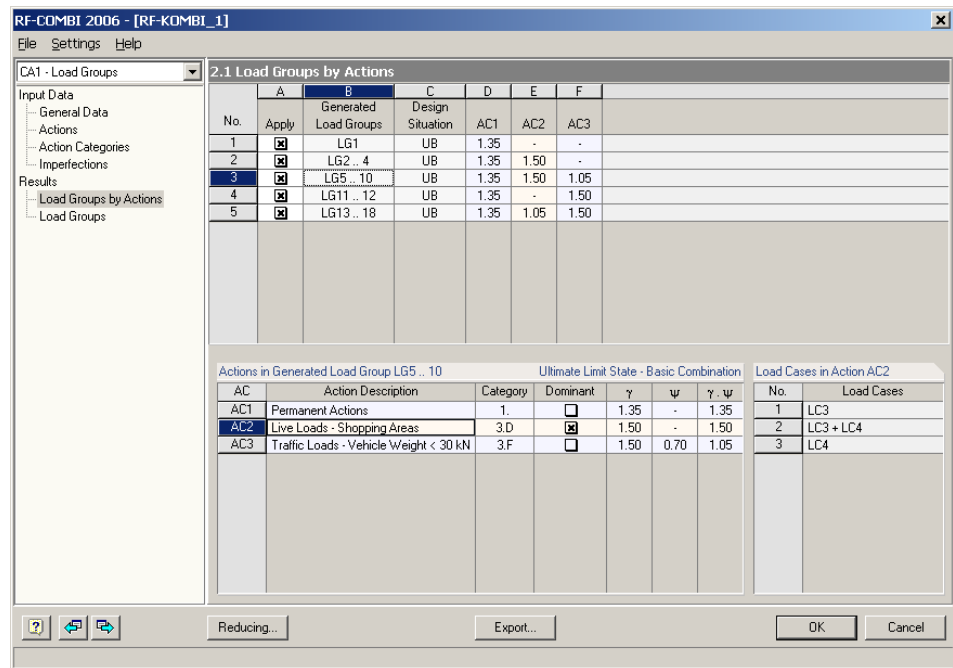

Figure 3.28: Mask 2.1 *Load Groups by Actions*

The upper part of this mask presents several columns. In the first column, the *No.* of every line is specified. Column *Apply* controls whether the load group is to be exported to RFEM, column *Generated Load Groups* shows which load groups belong to each result. Column *Design Situation* specifies the situation for which the load groups have been generated. Here, the short symbols of mask 1.1 are used. In the remaining columns, the actions with the relevant factors are listed.

If an entry in the upper part of this mask is clicked on, further details are displayed in the part below. In section *Actions in Generated Load Group*, the involved actions are listed along with their *Description* and *Category* (cf. mask 1.3).

Column *Dominant* marks the prevailing action. The action is dominant if it is applied as action $Q_{k,1}$ in equations 2.1, 2.2, 2.4, 2.5, 2.10, 2.11, 2.13 or 2.16. The coefficients γ, ψ and ξ in the following columns result from the relevant design situation and action category. The final column lists the factors for each action which are the products of the coefficients.

If a specific action has been selected in section *Actions in Generated Load Group*, the associated load cases are displayed in section *Load Cases in Action*. All possible combinations of these load cases within the action are listed which depend on the action category and the potential definition criteria of alternative load cases.

Figure 3.28 shows that altogether 18 load groups were generated for the design situations "Ultimate Limit State, Basic Combination". Five entries (i.e. lines in the upper part of the mask) show how the associated actions were applied in the equations for those design situations. The third line, for example, is *1.35 AC1 + 1.50 AC2 + 1.05 AC3*. When applying the actions in the adequate equation, six load groups are generated: *LG5..LG10*.

The first action AC1 was classified as "permanent" action category 1 in mask 1.3. In the generated load groups, coefficient γ =1.35 is therefore used. The second action AC2 was classified as "live load" within action category 3.D (shopping areas) in mask 1.3. For it, coefficient γ =1.50 is used in the generated load groups. AC2 is the dominant action which may occur as *LC3* or *LC3 + LC4* or *LC4*. The third action AC3 was classified as "traffic load" within action category 3.F (vehicle weight $<$ 30 kN) in mask 1.3. In the generated load groups, coefficients $\gamma * \psi$=1.50 * 0.70 = 1.05 are used (as AC2 is assumed as the dominant action within this third line).

3.4.1.2 Mask 2.2 Load Groups

Mask *2.2 Load Groups* consists of two parts. In the upper part, all generated load groups are listed. The details of the selected load group are specified in the part below.
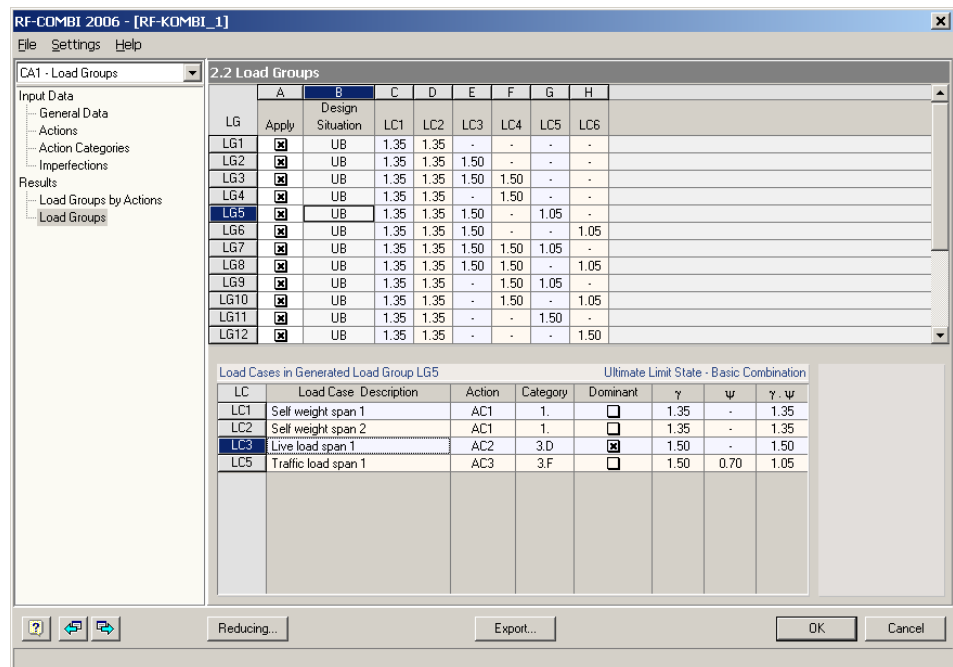

Figure 3.29: Mask 2.1 *Load Groups*

The upper part of this mask presents several columns. In the first column *LG*, the numbers of the generated load groups are listed. Column *Apply* controls whether the load group is to be exported to RFEM. This column is synchronized with the previous results mask 2.1. Column *Design Situation* specifies the situation for which the load groups have been generated. In the remaining columns, the generated load groups are listed.

If an entry in the upper part of this mask is clicked on, further details are displayed in the part below. In section *Load Cases in Generated Load Group*, all load cases represented in the selected load group are listed along with their possible *Description*. In column *Action*, the action number is shown that the relevant load case was allocated to in mask 1.2. The action category is specified in column *Category*. Column *Dominant* marks the prevailing action within the selected load group. The coefficients γ, ψ and ξ in the following columns result from the relevant design situation and action category. The final column lists the factors for each load case which are the products of the coefficients.

Figure 3.29 shows the first twelve load groups of altogether 18 generated load groups. LG5 consists of 1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.05 LC5. Load cases LC1 and LC2 are part of action AC1 which was classified as action category 1 ("permanent actions") in mask 1.3. Thus, both load cases are multiplied by factor $\gamma = 1.35$. Load case LC3 is part of action AC2 which was classified as action category 3.D ("live loads – shopping areas"). In LG5, it is the dominant load case and is thus multiplied by factor $\gamma = 1.50$. Load case LC5 is part of action AC3 that was classified as category 3.F ("traffic loads – vehicle weight < 30 kN"). In LG5, this load case is multiplied by factor $\gamma * \psi = 1.50 * 0.70 = 1.05$.

Comparing figures 3.27 and 3.28, it will be noticed that the third line of the generated load groups *1.35 AC1+1.50 AC2+1.05 AC3* in figure 3.28 includes load groups LG5..LG10 that are described in detail in figure 3.29:

LG5:   1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.05 LC5
LG6:   1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.05 LC6
LG7:   1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.50 LC4 + 1.05 LC5
LG8:   1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.50 LC4 + 1.05 LC6
LG9:   1.35 LC1 + 1.35 LC2 + 1.50 LC4 + 1.05 LC5
LG10:   1.35 LC1 + 1.35 LC2 + 1.50 LC4 + 1.05 LC6

Action AC1 comprises LC1 and LC2. This is a permanent action so that both load cases can only appear together. Action AC2 which comprises LC3 and LC4 is an accidental action. Thus, three combinations are possible: LC3, LC3 + LC4, LC4. Action AC3 includes LC5 and LC6. This is an accidental action, too. LC5 and LC6 were defined as alternative load cases so that either LC5 or LC6 is possible. Consequently, *1.35 AC1 + 1.50 AC2 + 1.05 AC3* stands for 1 * 3 * 2 = 6 load groups altogether, labeled as *LG5..LG10*.

In mask 2.2, it is thus possible to determine the associated load groups from every line of the previous mask. All possible combinations are identified unless option *Reduce Possible Load Groups by Examining RFEM Results* has been activated in mask 1.1. By this option, the generation is confined to the relevant load groups only so that a great number of possible load groups are neglected for mask 2.2.

3.4.2 Generated Load Combinations

3.4.2.1 Mask 2.1 Load Combinations by Actions

Mask *2.1 Load Combinations by Actions* consists of two parts. In the upper part, the generated load combinations are generally listed by actions. The details of the selected line are specified in the part below.
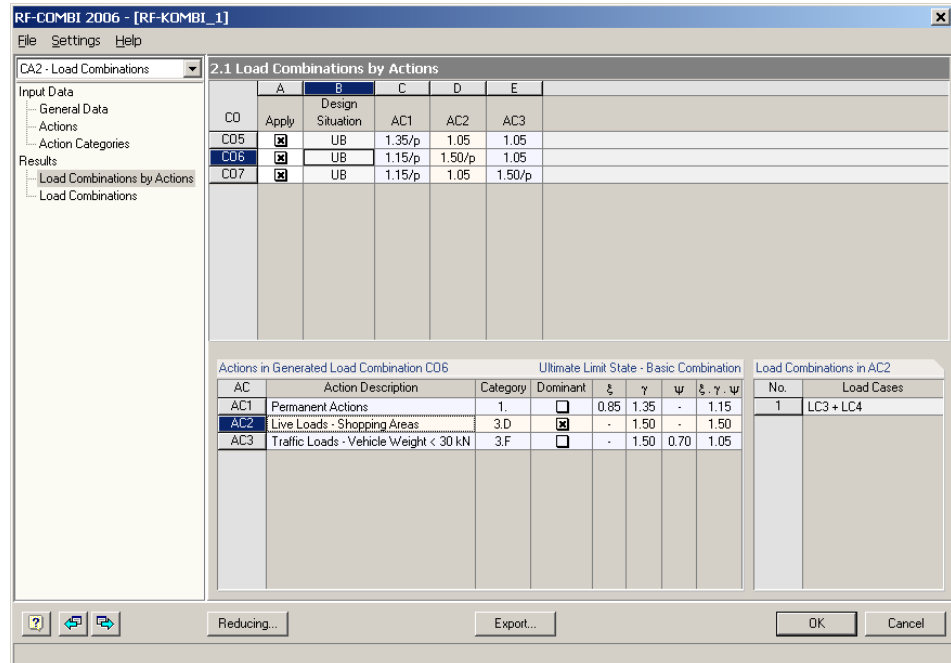

Figure 3.30: Mask 2.1 *Load Combinations by Actions*

This mask is analogous to mask *Load Groups by Actions* that is described in chapter 3.4.1.1 (p. 28).

Figure 3.30 shows the results of the example that had been used for figures 3.28 and 3.29. Here, three load combinations were generated for the design situations "Ultimate Limit State, Basic Combination": CO5, CO6 and CO7. This implies that four internal combinations of load cases were generated, too.

Load combination CO6, for example, is *1.15 AC1/p + 1.50 AC2/p + 1.05 AC3*. The label "/p" means that the action is considered as "permanent" within the combination. If there is no label, it is a "conditional" action. The first action AC1 in CO6 was classified as "permanent" action category *1* in mask 1.3. In the generated load combination, coefficients $\xi * \gamma = 0.85 * 1.35 = 1.15$ are applied. The second action AC2 was classified as "live load" within action category *3.C* (congregation areas) in mask 1.3. For it, coefficient $\gamma = 1.50$ is used in the generated load combination. AC2 is the dominant action which includes the load cases LC3 and LC4. Therefore, the internal load combination CO2 is *LC3 + LC4*. It contains all possible combinations of these two load cases in action AC2. The third action AC3 was classified as "traffic load" within action category *3.F* (vehicle weight < 30 kN). In the generated load combination, coefficients $\gamma * \psi = 1.50 * 0.70 = 1.05$ are used as AC2 is the dominant action.

3.4.2.2 Mask 2.2 Load Combinations

Mask *2.2 Load Combinations* consists of two parts. In the upper part, all generated load combinations are listed. The details of the selected load combination are specified in the part below.
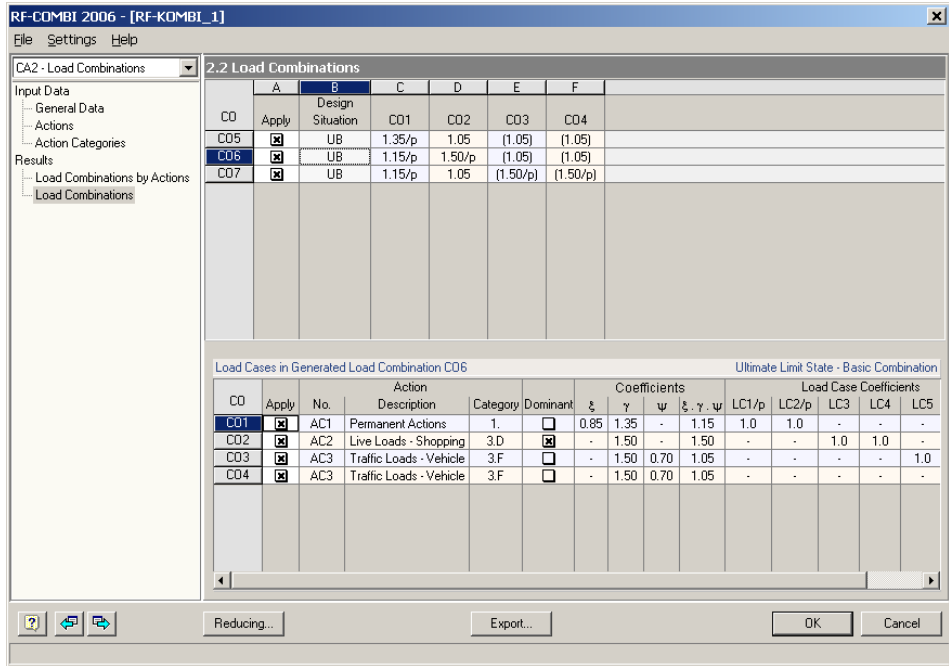

Figure 3.31: Mask 2.2 *Load Combinations*

This mask is analogous to mask *Load Groups* which is described in chapter 3.4.1.2 (p. 29).

Figure 3.31 shows three load combinations that were generated: CO5, CO6 and CO7. The combination criterion of e.g. CO6 is *1.15 CO1/p + 1.50 CO2/p + 1.05 CO3 or 1.05 CO4*. The first internal load combination CO1 includes action AC1 which was classified as action category *1* ("permanent actions") in mask 1.3, consisting of the two permanent load cases LC1 and LC2. Thus, both AC1 and CO1 are multiplied by factor $\xi * \gamma = 0.85 * 1.35 = 1.15$ in load combination CO6. The second internal combination CO2 is part of action AC2 which was classified as action category *3.C* ("live loads – congregation areas"). In CO6, it is the dominant action. Thus, CO2 is multiplied by factor $\gamma = 1.50$ and labeled as "permanent" within load combination CO6. The internal load combinations CO3 and CO4 are part of action AC3 that was classified as category *3.F* ("traffic loads – vehicle weight < 30 kN"). In CO6, these alternative combinations are multiplied by factors $\gamma * \psi = 1.50 * 0.70 = 1.05$.

3.5   Menus

The menu bar contains all functions to handle the RF-COMBI cases. Any menu is activated by a mouse click or by pressing the [Alt] key in combination with the underlined letter.

3.5.1   File

New Case

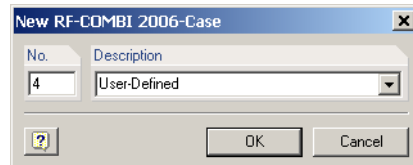A new RF-COMBI case, i.e. an independent set of input and output data, can be created.

Figure 3.32: Dialog *New RF-COMBI Case*

The *Number* and the *Description* of the new RF-COMBI case have to be specified in this dialog. The description can also be chosen from the list that contains all previous entries.

Rename Case

The current RF-COMBI case can be renamed.
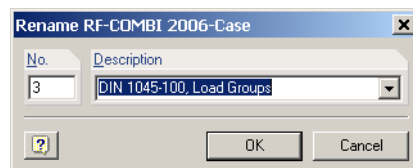
Figure 3.33: Dialog *Rename RF-COMBI Case*

It is possible to change the *Description* and/or the *Number*.

Copy Case

All data of the current RF-COMBI case can be copied to a new case.
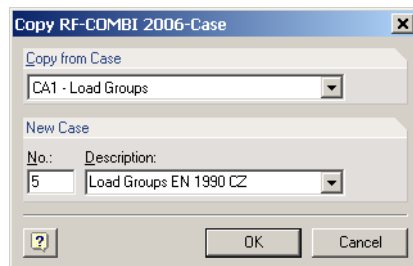
Figure 3.34: Dialog *Copy RF-COMBI Case*

It is possible to change the *Number* of the new RF-COMBI case and to enter a *Description*.

Delete Case

An RF-COMBI case can also be deleted. Select the specific RF-COMBI case from the list and delete it by pressing [OK].
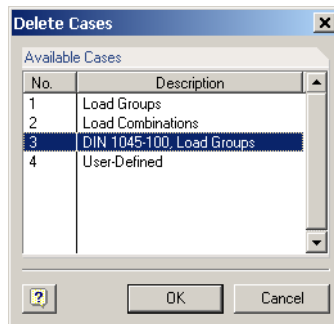
Figure 3.35: Dialog *Delete RF-COMBI Case*

3.5.2 Help

The help function is called up.

4. Results

4.1 Printing the Results

Before the numerical results can be printed, RF-COMBI must be closed. Then, the global RFEM printout report can be called up. It provides all options to select or arrange the printout which are described in detail in the RFEM manual.

There are specific registers available for the RF-COMBI data in the *Selection* dialog. Those registers are shown when *RF-COMBI 2006* is selected in the *Programs* list to the left.
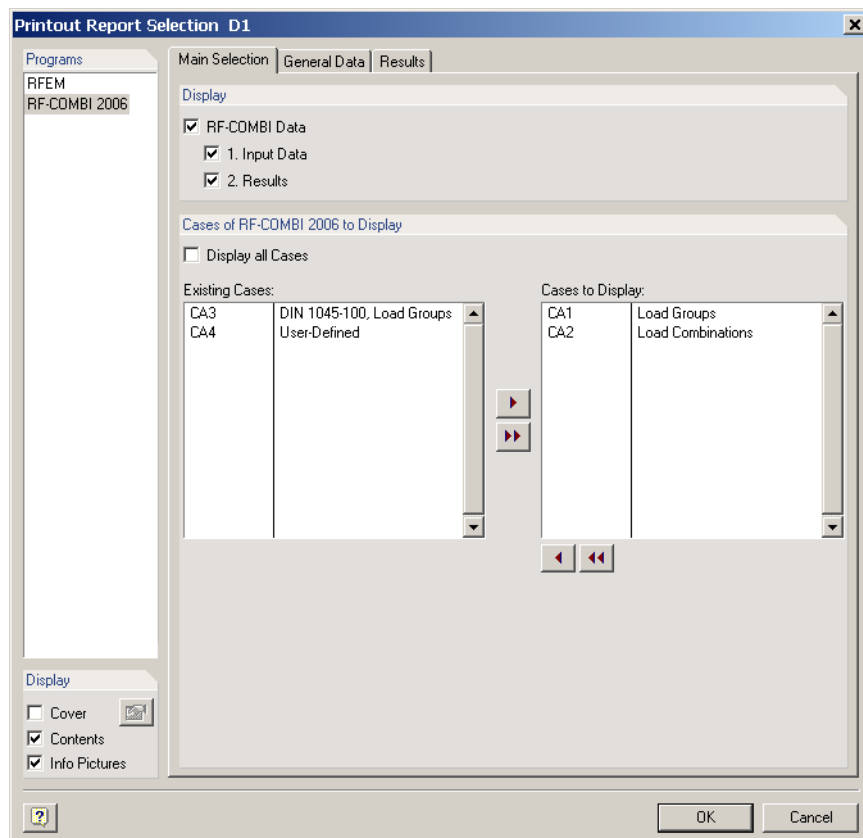
Figure 4.1: Dialog *Printout Report Selection*: RF-COMBI data

5. Examples

5.1 Single-Span Girder with Cantilever according to DIN 1055-100

Construction

A single-span girder with cantilever is charged with permanent load, live loads and traffic loads. The loads are split into two load cases each, i.e. span load and cantilever load.

Load Cases	Actions	Action Categories
LC1, LC2	AC1	Permanent
LC3, LC4	AC2	Live Loads, 3.C – Congregation Areas $\psi_0 = 0.70$, $\psi_1 = 0.70$, $\psi_2 = 0.60$
LC5 or LC6	AC3	Traffic Loads, 3.F – Vehicle Weight < 30 kN $\psi_0 = 0.70$, $\psi_1 = 0.70$, $\psi_2 = 0.60$

Table 5.1: Load Cases, Actions and Action Categories

Basic combination-type load groups are to be generated for ultimate limit state design situations according to DIN 1055-100.

Data Input

In mask 1.1, the generation of load groups according to DIN 1055-100 for the design situations "Ultimate Limit State, Basic Combination" UB is defined. In order to differentiate between favorable and unfavorable permanent actions, option *Generate supplementary combinations from favorable permanent actions* is enabled.
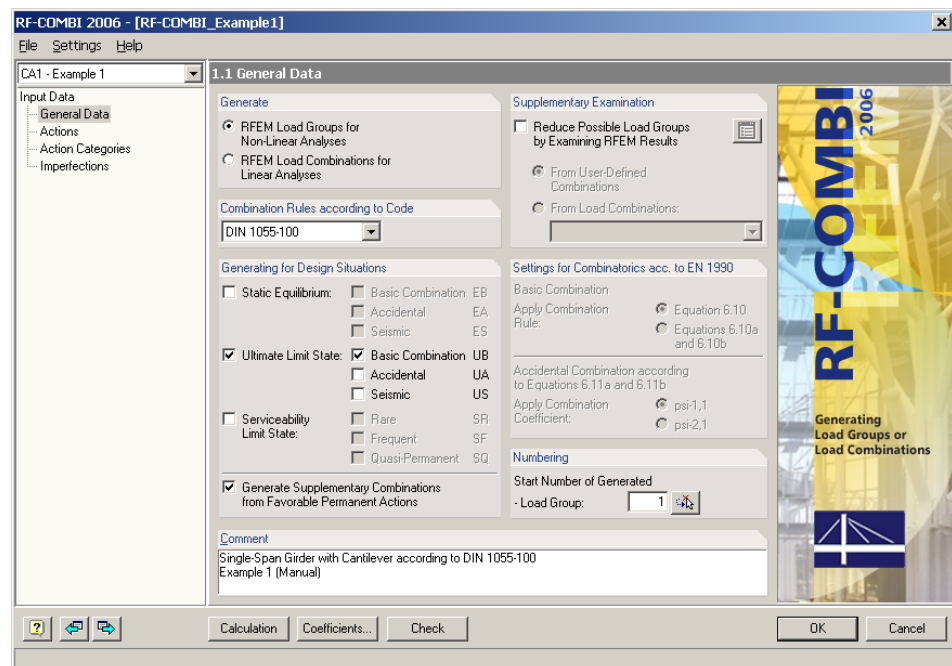
Figure 5.1: Mask 1.1 *General Data*

When mask 1.2 is called up, action AC1 is defined automatically, and load case LC1 is allocated to this action. It is possible to add an *Action Description*.

LC2 is the permanent cantilever load and can thus be included in action AC1 via the adequate button or a double-click.
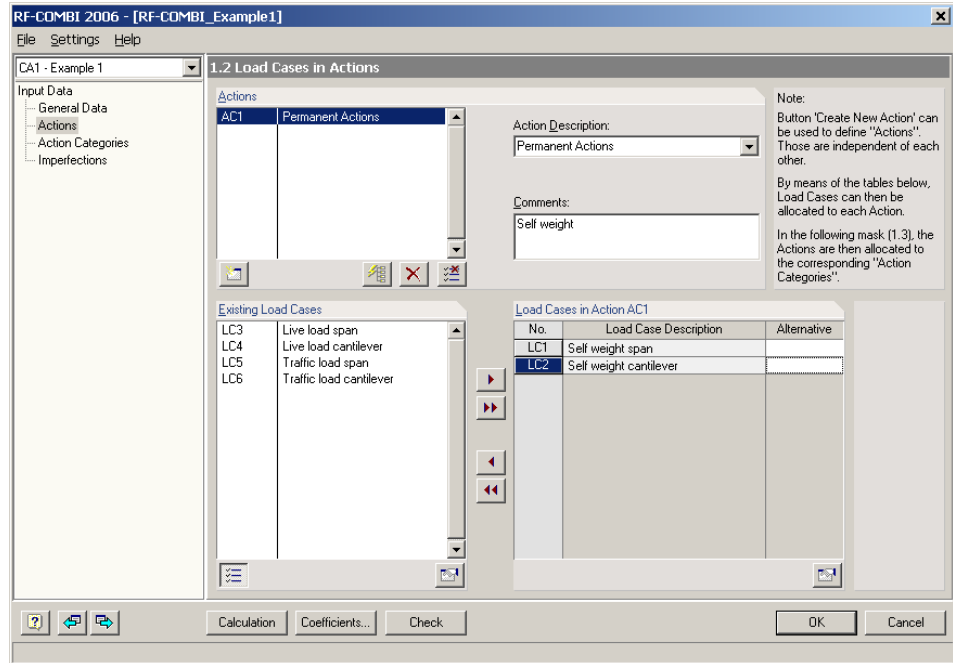
Figure 5.2: Mask 1.2 *Load Cases in Action* – Action AC1 (LC1 and LC2)

Actions AC2 and AC3 are then created via button [Create new Action] in section *Actions*.

Load cases LC3 and LC4 are assigned to action AC2, load cases LC5 and LC6 to action AC3. The latter are alternative load cases, as the vehicle is either on the span or on the cantilever. Therefore, load cases LC5 and LC6 are supplemented with an identical description in column *Alternative*.
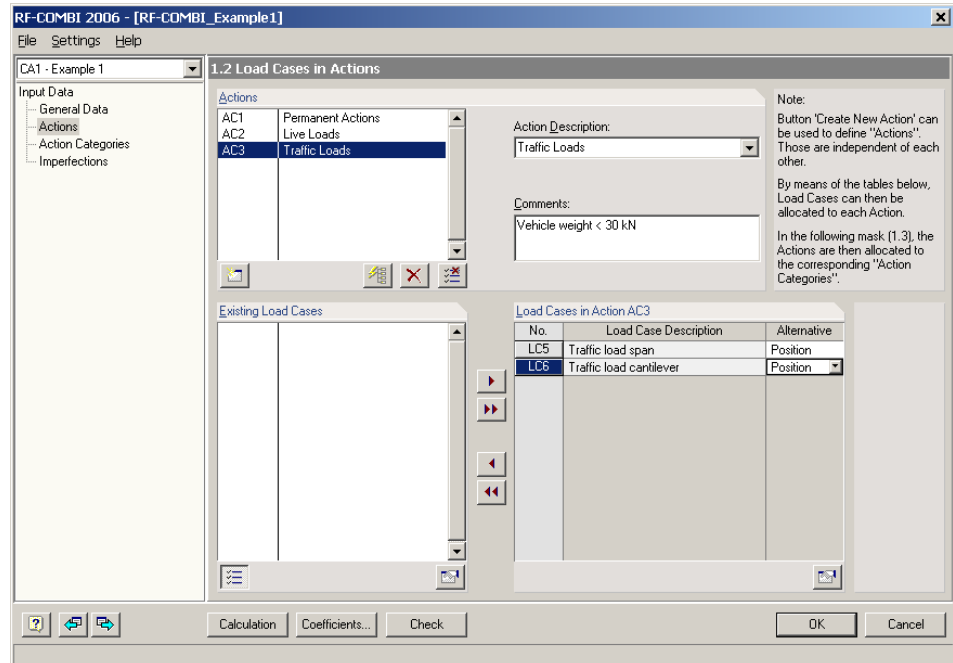
Figure 5.3: Mask 1.2 *Load Cases in Actions* – Action AC3 (alternative load cases LC5 and LC6)

The actions are then assigned to action categories in mask 1.3 *Actions in Action Categories*.
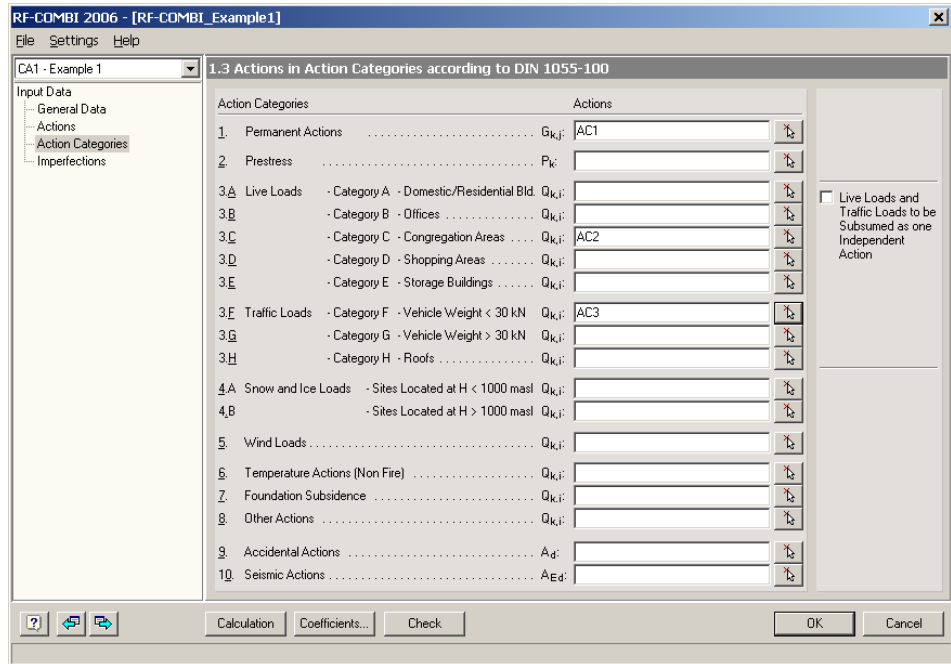

Figure 5.4: Mask 3.1 *Actions in Action Categories*

After this, the input of data is complete. There are no imperfections in this example.

Results

For these design situations, 36 load groups are generated according to equation 2.1. In mask 2.1, they are subsumed in ten lines.
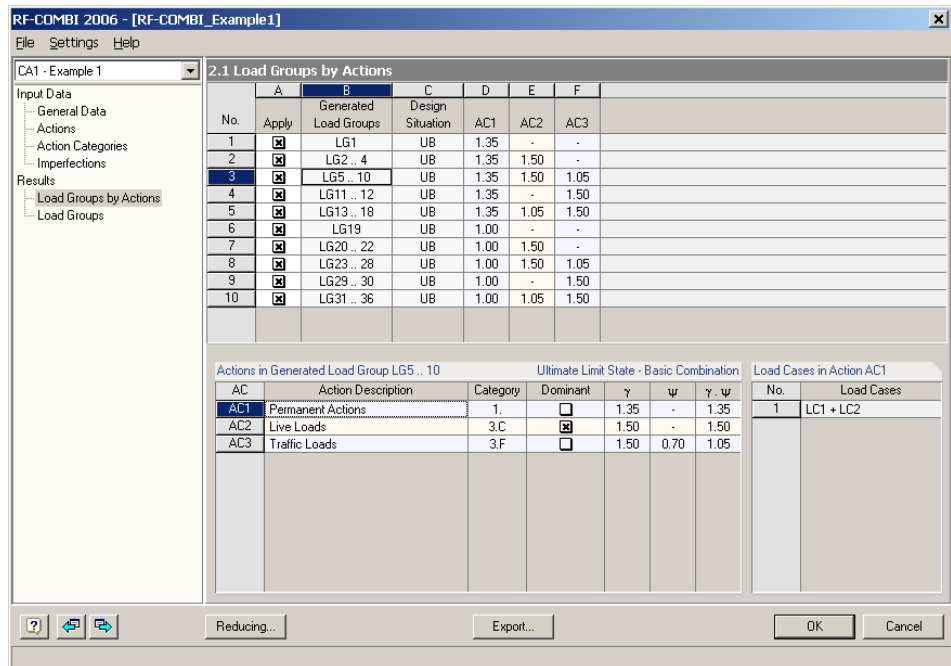

Figure 5.5: Mask 2.1 *Load Groups by Actions*

The single load groups are listed in mask 2.2.

2.2 Load Groups

LG	Apply	Design Situation	LC1	LC2	LC3	LC4	LC5	LC6
LG1	☒	UB	1.35	1.35	-	-	-	-
LG2	☒	UB	1.35	1.35	1.50	-	-	-
LG3	☒	UB	1.35	1.35	1.50	1.50	-	-
LG4	☒	UB	1.35	1.35	-	1.50	-	-
LG5	☒	UB	1.35	1.35	1.50	-	1.05	-
LG6	☒	UB	1.35	1.35	1.50	-	-	1.05
LG7	☒	UB	1.35	1.35	1.50	1.50	1.05	-
LG8	☒	UB	1.35	1.35	1.50	1.50	-	1.05
LG9	☒	UB	1.35	1.35	-	1.50	1.05	-
LG10	☒	UB	1.35	1.35	-	1.50	-	1.05
LG11	☒	UB	1.35	1.35	-	-	1.50	-
LG12	☒	UB	1.35	1.35	-	-	-	1.50

LG	Apply	Design Situation	LC1	LC2	LC3	LC4	LC5	LC6
LG13	☒	UB	1.35	1.35	1.05	-	1.50	-
LG14	☒	UB	1.35	1.35	1.05	-	-	1.50
LG15	☒	UB	1.35	1.35	1.05	1.05	1.50	-
LG16	☒	UB	1.35	1.35	1.05	1.05	-	1.50
LG17	☒	UB	1.35	1.35	-	1.05	1.50	-
LG18	☒	UB	1.35	1.35	-	1.05	-	1.50
LG19	☒	UB	1.00	1.00	-	-	-	-
LG20	☒	UB	1.00	1.00	1.50	-	-	-
LG21	☒	UB	1.00	1.00	1.50	1.50	-	-
LG22	☒	UB	1.00	1.00	-	1.50	-	-
LG23	☒	UB	1.00	1.00	1.50	-	1.05	-
LG24	☒	UB	1.00	1.00	1.50	-	-	1.05

LG	Apply	Design Situation	LC1	LC2	LC3	LC4	LC5	LC6
LG25	☒	UB	1.00	1.00	1.50	1.50	1.05	-
LG26	☒	UB	1.00	1.00	1.50	1.50	-	1.05
LG27	☒	UB	1.00	1.00	-	1.50	1.05	-
LG28	☒	UB	1.00	1.00	-	1.50	-	1.05
LG29	☒	UB	1.00	1.00	-	-	1.50	-
LG30	☒	UB	1.00	1.00	-	-	-	1.50
LG31	☒	UB	1.00	1.00	1.05	-	1.50	-
LG32	☒	UB	1.00	1.00	1.05	-	-	1.50
LG33	☒	UB	1.00	1.00	1.05	1.05	1.50	-
LG34	☒	UB	1.00	1.00	1.05	1.05	-	1.50
LG35	☒	UB	1.00	1.00	-	1.05	1.50	-
LG36	☒	UB	1.00	1.00	-	1.05	-	1.50

Figure 5.6: Mask 2.2 *Load Groups*

Comparing mask 2.1 (figure 5.5) and mask 2.2 (figure 5.6), notice that the third line of the generated load groups *1.35 AC1+1.50 AC2+1.05 AC3* in mask 2.1 includes load groups LG5..LG10 that are described in detail in mask 2.2:

- LG5: 1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.05 LC5
- LG6: 1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.05 LC6
- LG7: 1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.50 LC4 + 1.05
- LG8: 1.35 LC1 + 1.35 LC2 + 1.50 LC3 + 1.50 LC4 + 1.05 LC6
- LG9: 1.35 LC1 + 1.35 LC2 + 1.50 LC4 + 1.05 LC5
- LG10: 1.35 LC1 + 1.35 LC2 + 1.50 LC4 + 1.05 LC6

Action AC1 comprises LC1 and LC2. This is a permanent action so that both load cases must appear together. Action AC2 which comprises LC3 and LC4 is an accidental action. Thus, three combinations are possible: LC3, LC3 + LC4, LC4. Action AC3 includes LC5 and LC6. This is an accidental action, too. LC5 and LC6 were defined as alternative load cases so that either LC5 or LC6 is possible. Consequently, *1.35 AC1 + 1.50 AC2 + 1.05 AC3* stands for 1 * 3 * 2 = 6 load groups altogether, labeled as *LG5..LG10*.

Note

Two permanent loads (LC1 - span, LC2 - cantilever) have been included in action AC1. Thus, both load cases always have the same coefficients within the load groups: 1.35 or 1.00. If LC1 and LC2 are independent from each other, they must be allocated to different actions.

Load Cases	Actions	Action Categories
LC1	AC1	Permanent
LC2	AC2	Permanent
LC3, LC4	AC3	Live Loads, 3.C – Congregation Areas $\psi_0 = 0,70$, $\psi_1 = 0,70$, $\psi_2 = 0,60$, $\psi_2 = 0,60$
LC5 or LC6	AC4	Traffic Loads, 3.F – Vehicle Weight < 30 kN $\psi_0 = 0,70$, $\psi_1 = 0,70$, $\psi_2 = 0,60$

Table 5.2: Load Cases, Actions and Action Categories

In this case, load cases LC1 and LC2 are multiplied by different partial safety coefficients, which results in 72 load groups altogether.

Figure 5.7: Mask 2.1 *Load Groups by Actions* – LC1 and LC2 as different actions (AC1 and AC2)

When the generated load groups are finally to be transferred to RFEM, the enveloping load combination can also be created from these load groups. This can be specified in section *Either/Or Load Combination* in the *Export* dialog.
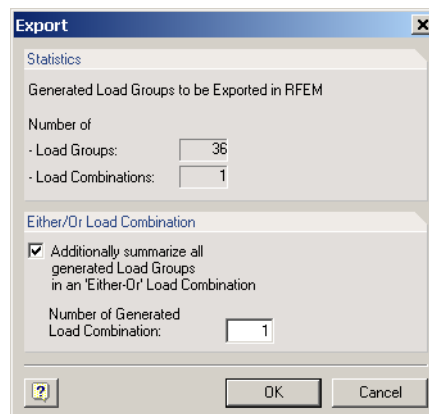

Figure 5.8: Dialog *Export* – Either/Or Load Combination

Load combination CO1 is generated: *LG1/p or LG2/p or LG3/p or LG4/p .... or LG36/p*

5.2 Framed Structure with Imperfections according to EN 1990 CEN

Construction

A skeleton structure is charged with permanent load, live loads, wind and snow loads. Additionally, imperfections-type loads are applied.

Load Cases	Actions	Action Categories
LC1	AC1	Permanent
LC2, LC3	AC2	Live Loads, 3.B – Offices $\psi_0 = 0.70$, $\psi_1 = 0.50$, $\psi_2 = 0.30$
LC4, LC5	AC3	Live Loads, 3.D – Shopping Areas $\psi_0 = 0.70$, $\psi_1 = 0.70$, $\psi_2 = 0.60$
LC6 or LC7	AC4	5. – Wind Loads $\psi_0 = 0.60$, $\psi_1 = 0.20$, $\psi_2 = 0$
LC8	AC5	4.A – Snow and Ice Loads – Sites Located at H < 1000 masl $\psi_0 = 0.50$, $\psi_1 = 0.20$, $\psi_2 = 0$
LC9, LC10		Imperfections

Table 5.3: Load Cases, Actions and Action Categories

Basic combination-type load groups are to be generated for ultimate limit state design situations according to EN 1990 CEN.

Data Input

In mask 1.1, the generation of load groups according to EN 1990 CEN for the design situations "Ultimate Limit State, Basic Combination" is defined.

When mask 1.2 is called up, action AC1 is defined automatically, and load case LC1 is allocated to this action. It is possible to add an *Action Description*.

Actions AC2 to AC5 are then created via button [Create new Action] in section *Actions*.

Load cases LC2 and LC3 are assigned to action AC2 (offices), load cases LC4 and LC5 to action AC3 (shopping areas) as different combination coefficients ψ_2 are applicable. When allocating the alternative load cases LC6 and LC7 to action AC4, they are supplemented with an identical description (e.g. *Wind*) in column *Alternative*.
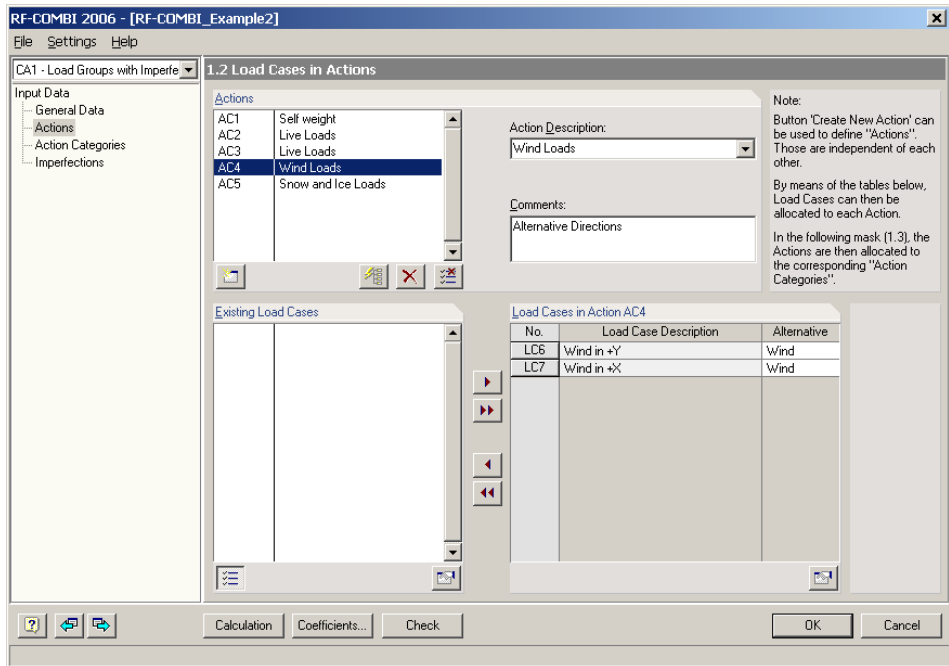
Figure 5.9: Mask 1.2 *Load Cases in Actions* – Action AC4

Load case LC8 is finally assigned to action AC5.

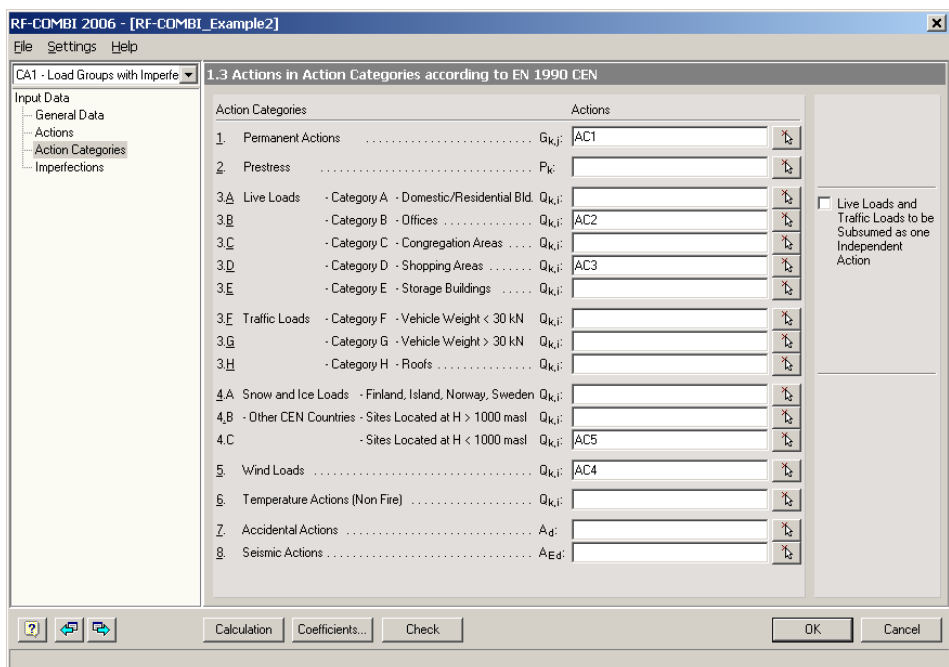In mask 1.3, all five actions are then allocated to the adequate action categories.

Figure 5.10: Mask 1.3 *Actions in Action Categories*

When calling up mask 1.4, the imperfection-type load cases LC9 and LC10 are listed. In order to consider the load cases in the generated load groups, they are included in the list *Imperfection-Type Load Cases in Combinatorics*.

As those two imperfections never appear simultaneously, an identical description is entered for both load cases in column *Alternative*.
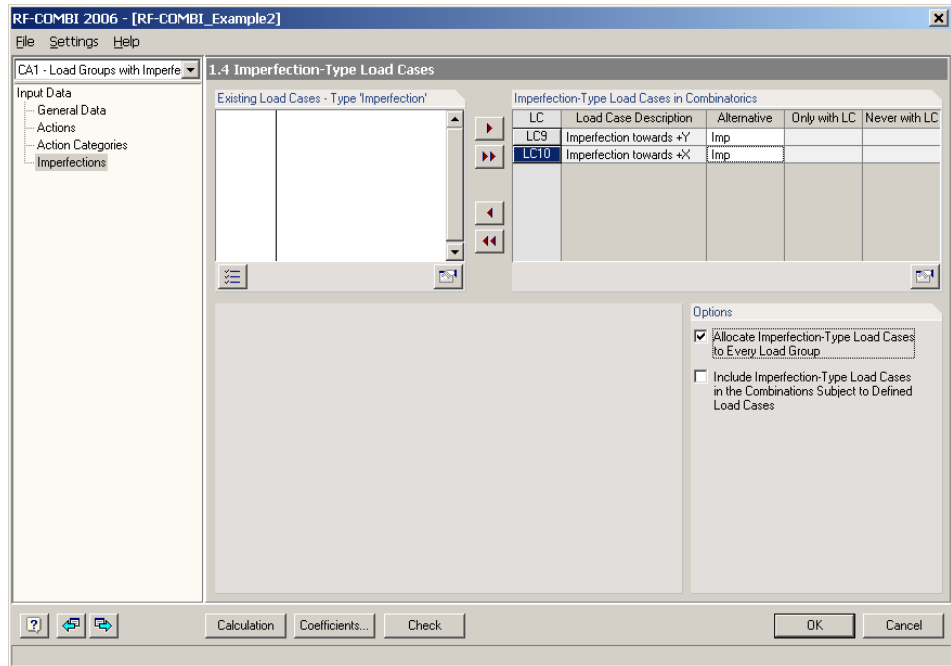
Figure 5.11: Mask 1.4 *Imperfection-Type Load Cases* – LC9 and LC10 in combinatorics

Load groups are analyzed according to 2nd order theory. Therefore, every load group ought to include an imperfection. This is achieved by enabling option *Allocate Imperfection-Type Load Cases to Every Load Group*.

Results

For these design situations, a total of 514 load groups are generated according to equation 2.10. In mask 2.1, they are subsumed in 33 lines.

2.1 Load Groups by Actions

	A	B	C	D	E	F	G	H
No.	Apply	Generated Load Groups	Design Situation	AC1	AC2	AC3	AC4	AC5
1	☒	LG1 .. 2	UB	1.35	-	-	-	-
2	☒	LG3 .. 8	UB	1.35	1.50	-	-	-
3	☒	LG9 .. 26	UB	1.35	1.50	1.05	-	-
4	☒	LG27 .. 62	UB	1.35	1.50	1.05	0.90	-
5	☒	LG63 .. 98	UB	1.35	1.50	1.05	0.90	0.75
6	☒	LG99 .. 116	UB	1.35	1.50	1.05	-	0.75
7	☒	LG117 .. 128	UB	1.35	1.50	-	0.90	-
8	☒	LG129 .. 140	UB	1.35	1.50	-	0.90	0.75
9	☒	LG141 .. 146	UB	1.35	1.50	-	-	0.75
10	☒	LG147 .. 152	UB	1.35	-	1.50	-	-
11	☒	LG153 .. 170	UB	1.35	1.05	1.50	-	-
12	☒	LG171 .. 206	UB	1.35	1.05	1.50	0.90	-
13	☒	LG207 .. 242	UB	1.35	1.05	1.50	0.90	0.75
14	☒	LG243 .. 260	UB	1.35	1.05	1.50	-	0.75
15	☒	LG261 .. 272	UB	1.35	-	1.50	0.90	-
16	☒	LG273 .. 284	UB	1.35	-	1.50	0.90	0.75
17	☒	LG285 .. 290	UB	1.35	-	1.50	-	0.75
18	☒	LG291 .. 294	UB	1.35	-	-	1.50	-
19	☒	LG295 .. 306	UB	1.35	1.05	-	1.50	-
20	☒	LG307 .. 342	UB	1.35	1.05	1.05	1.50	-
21	☒	LG343 .. 378	UB	1.35	1.05	1.05	1.50	0.75
22	☒	LG379 .. 390	UB	1.35	1.05	-	1.50	0.75
23	☒	LG391 .. 402	UB	1.35	-	1.05	1.50	-
24	☒	LG403 .. 414	UB	1.35	-	1.05	1.50	0.75
25	☒	LG415 .. 418	UB	1.35	-	-	1.50	0.75
26	☒	LG419 .. 420	UB	1.35	-	-	-	1.50
27	☒	LG421 .. 426	UB	1.35	1.05	-	-	1.50
28	☒	LG427 .. 444	UB	1.35	1.05	1.05	-	1.50
29	☒	LG445 .. 480	UB	1.35	1.05	1.05	0.90	1.50
30	☒	LG481 .. 492	UB	1.35	1.05	-	0.90	1.50
31	☒	LG493 .. 498	UB	1.35	-	1.05	-	1.50
32	☒	LG499 .. 510	UB	1.35	-	1.05	0.90	1.50
33	☒	LG511 .. 514	UB	1.35	-	-	0.90	1.50

Figure 5.12: Mask 2.1 *Load Groups by Actions*

The detailed results of mask 2.2 demonstrate that the imperfections are applied alternately.
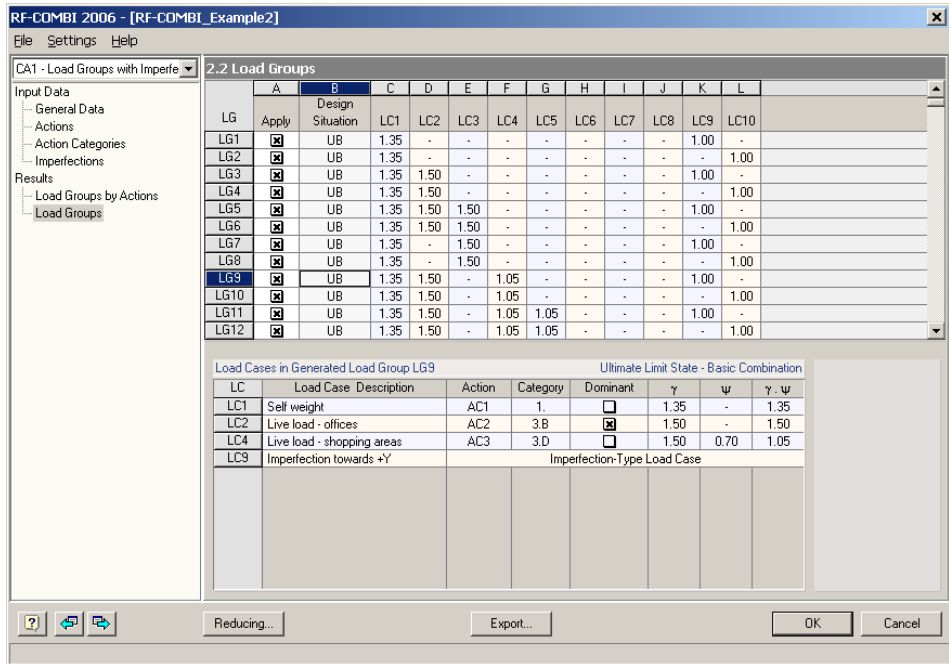

Figure 5.13: Mask 2.2 *Load Groups*

Note

Often it is evident that specific imperfections depend on certain load cases or do not make sense in combination with other load cases. In our example, LC6 is defined as *Wind in +Y*, LC7 as *Wind in +X*. Imperfection LC9 is *Drift towards +Y*, LC10 is *Drift towards +X*. It does not make much sense, therefore, to combine load cases LC6 and LC10 or LC7 and LC9.

This can be used in RF-COMBI to reduce the number of generated load groups via option *Include Imperfection-Type Load Cases in the Combinations Subject to Defined Load Cases*. For these design situations, 322 load groups are generated instead of 514.
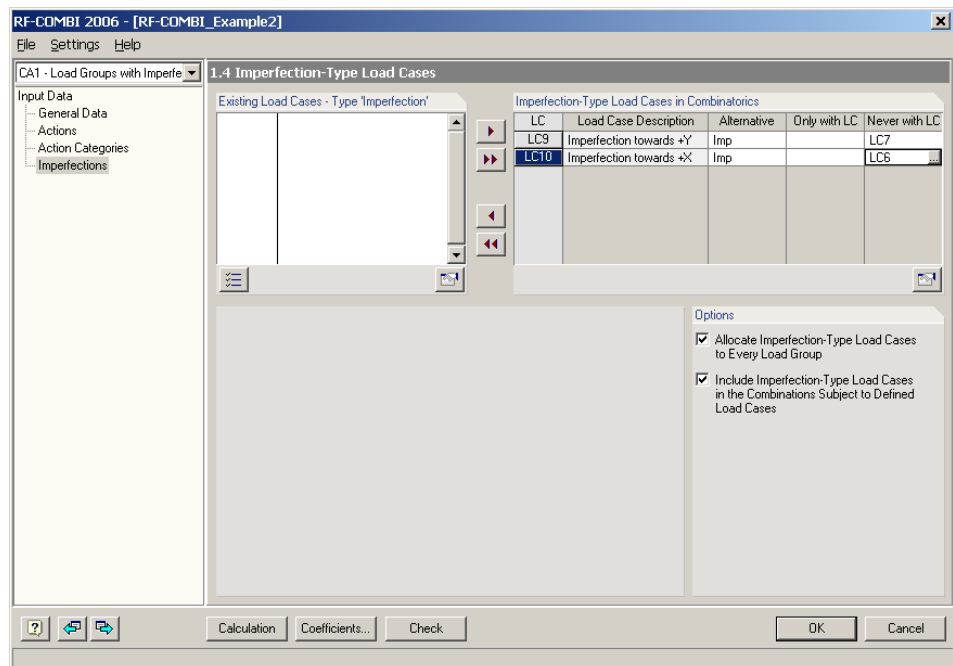

Figure 5.14: Mask 1.4 *Imperfection-Type Load Cases* – Imperfections subject to specific load cases

5.3   Wall according to EN 1990 CEN

Construction

A wall is charged with permanent load, live loads, traffic loads, snow and wind loads.

Load Cases	Actions	Action Categories
LC1	AC1	Permanent
LC2, LC3, LC4	AC2	Live Loads, 3.D – Shopping Areas
LC5	AC3	Traffic Loads, 3.F – Vehicle Weight < 30 kN
LC6	AC4	Snow and Ice Loads – Sites Located at H > 1000 masl
LC7 or LC8	AC5	Wind Loads

Table 5.4: Load Cases, Actions and Action Categories

Basic combination-type load groups are to be generated for ultimate limit state design situations according to EN 1990 CEN.

Data Input

In mask 1.1, the generation of load groups according to EN 1990 CEN for the design situations "Ultimate Limit State, Basic Combination" is defined. To economize on material, the *Combination Rule according to Equations 6.10a and 6.10b* is selected in section *Settings for Combinatorics*. Equations 6.10a and 6.10b correspond to equations 2.11 and 2.12 in this manual.
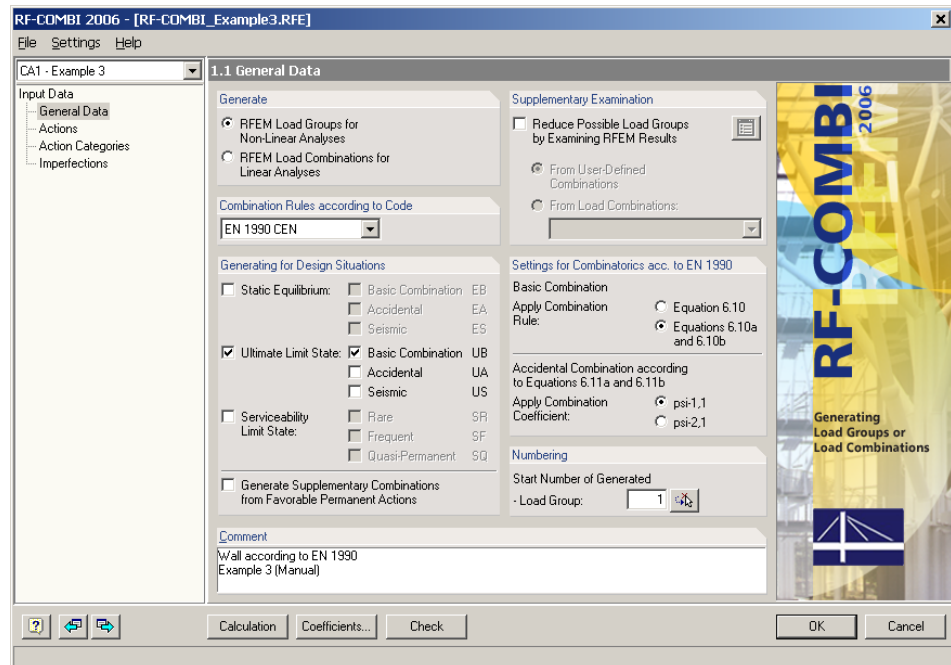

Figure 5.15: Mask 1.1 *General Data*

When mask 1.2 is called up, action AC1 is defined automatically, and load case LC1 is allocated to this action. The remaining load cases are listed in section *Existing Load Cases*.
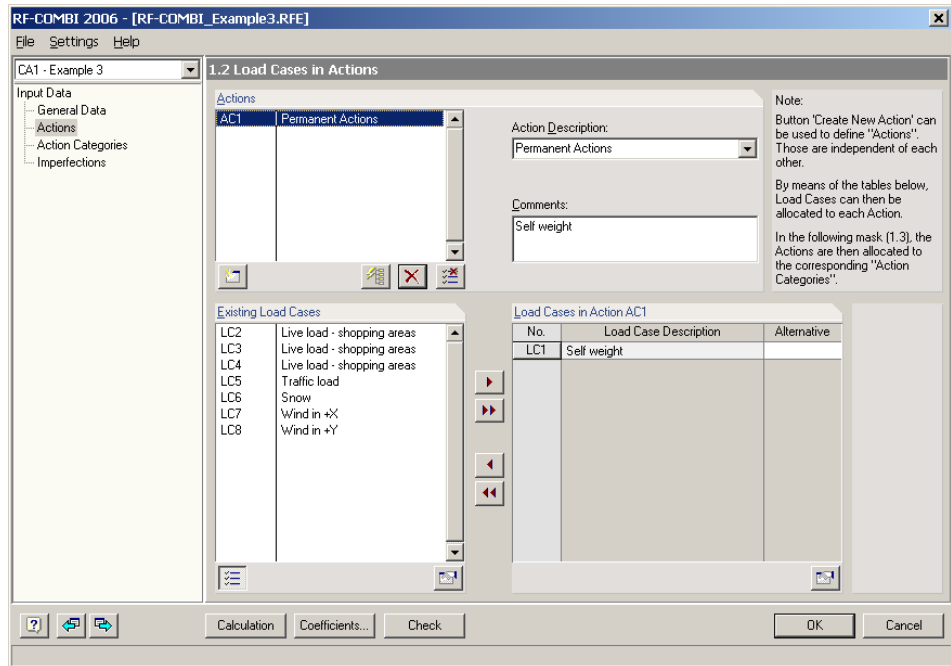
Figure 5.16: Mask 1.2 *Load Cases in Actions*

Actions AC2 to AC6 are then created via button [Create new Action] in section *Actions*.

Load cases LC2, LC3 and LC4 are assigned to action AC2, load case LC5 to action AC3 and load case LC6 to action AC4. When allocating the alternative load cases LC7 and LC8 to action AC5, they are to be supplemented with an identical description (e.g. *Wind*) in column *Alternative*.
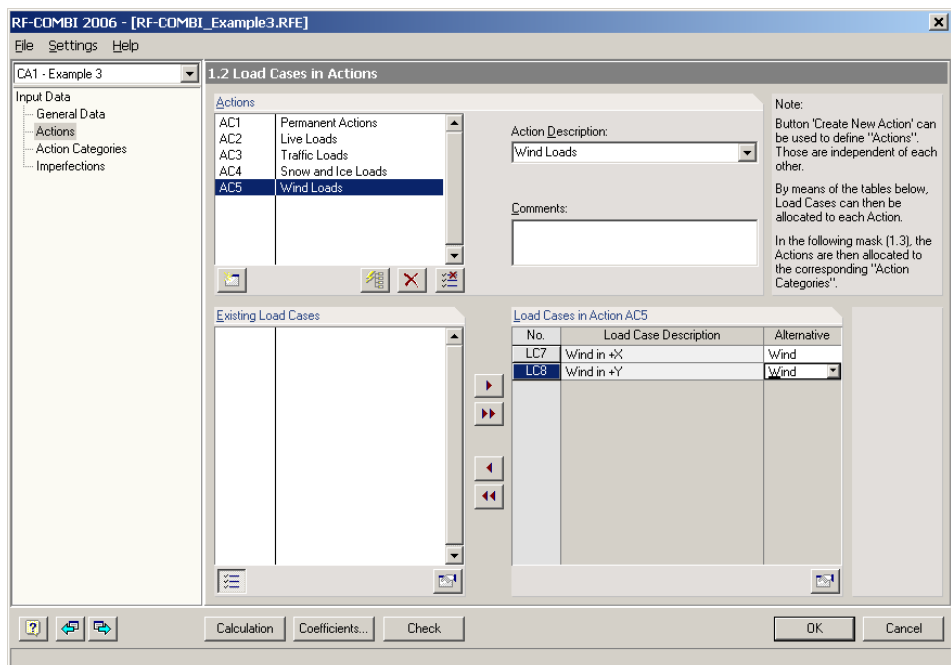

Figure 5.17: Mask 1.2 *Load Cases in Actions* – Action AC5

In mask 1.3, all five actions are then allocated to the adequate action categories.
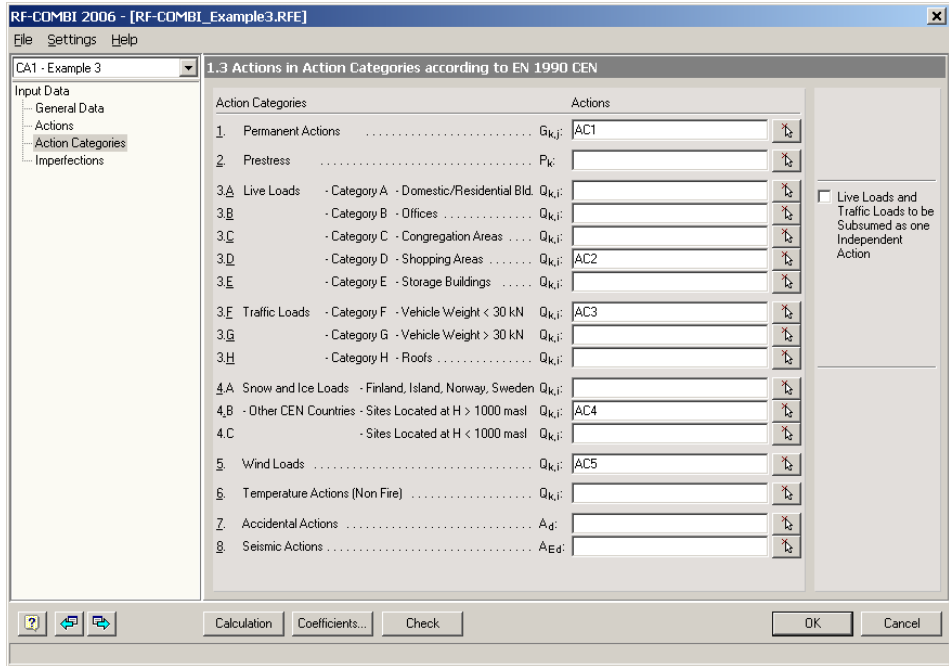
Figure 5.18: Mask 1.3 *Actions in Action Categories*

After this, the input of data is completed. There are no imperfections in this example.

Results

For these design situations, 341 load groups are generated. Load groups LG1 to LG96 are generated according to equation 2.11:

No.	A Apply	Generated Load Groups	Design Situation	D AC1	E AC2	F AC3	G AC4	H AC5
1	☒	LG1	UB	1.35	-	-	-	-
2	☒	LG2 .. 8	UB	1.35	1.05	-	-	-
3	☒	LG9 .. 15	UB	1.35	1.05	1.05	-	-
4	☒	LG16 .. 22	UB	1.35	1.05	1.05	1.05	-
5	☒	LG23 .. 36	UB	1.35	1.05	1.05	1.05	0.90
6	☒	LG37 .. 50	UB	1.35	1.05	1.05	-	0.90
7	☒	LG51 .. 57	UB	1.35	1.05	-	1.05	-
8	☒	LG58 .. 71	UB	1.35	1.05	-	1.05	0.90
9	☒	LG72 .. 85	UB	1.35	1.05	-	-	0.90
10	☒	LG86	UB	1.35	-	1.05	-	-
11	☒	LG87	UB	1.35	-	1.05	1.05	-
12	☒	LG88 .. 89	UB	1.35	-	1.05	1.05	0.90
13	☒	LG90 .. 91	UB	1.35	-	1.05	-	0.90
14	☒	LG92	UB	1.35	-	-	1.05	-
15	☒	LG93 .. 94	UB	1.35	-	-	1.05	0.90
16	☒	LG95 .. 96	UB	1.35	-	-	-	0.90

Figure 5.19: Mask 1.2 *Load Groups by Actions*

Load groups LG97 to LG341 are generated according to equation 2.12:

2.1 Load Groups by Actions

No.	Apply	Generated Load Groups	Design Situation	AC1	AC2	AC3	AC4	AC5
17	☒	LG97	UB	1.15	-	-	-	-
18	☒	LG98 .. 104	UB	1.15	1.50	-	-	-
19	☒	LG105 .. 111	UB	1.15	1.50	1.05	-	-
20	☒	LG112 .. 118	UB	1.15	1.50	1.05	1.05	-
21	☒	LG119 .. 132	UB	1.15	1.50	1.05	1.05	0.90
22	☒	LG133 .. 146	UB	1.15	1.50	1.05	-	0.90
23	☒	LG147 .. 153	UB	1.15	1.50	-	1.05	-
24	☒	LG154 .. 167	UB	1.15	1.50	-	1.05	0.90
25	☒	LG168 .. 181	UB	1.15	1.50	-	-	0.90
26	☒	LG182	UB	1.15	-	1.50	-	-
27	☒	LG183 .. 189	UB	1.15	1.05	1.50	-	-
28	☒	LG190 .. 196	UB	1.15	1.05	1.50	1.05	-
29	☒	LG197 .. 210	UB	1.15	1.05	1.50	1.05	0.90
30	☒	LG211 .. 224	UB	1.15	1.05	1.50	-	0.90
31	☒	LG225	UB	1.15	-	1.50	1.05	-
32	☒	LG226 .. 227	UB	1.15	-	1.50	1.05	0.90
33	☒	LG228 .. 229	UB	1.15	-	1.50	-	0.90
34	☒	LG230	UB	1.15	-	-	1.50	-
35	☒	LG231 .. 237	UB	1.15	1.05	-	1.50	-
36	☒	LG238 .. 244	UB	1.15	1.05	1.05	1.50	-
37	☒	LG245 .. 258	UB	1.15	1.05	1.05	1.50	0.90
38	☒	LG259 .. 272	UB	1.15	1.05	-	1.50	0.90
39	☒	LG273	UB	1.15	-	1.05	1.50	-
40	☒	LG274 .. 275	UB	1.15	-	1.05	1.50	0.90
41	☒	LG276 .. 277	UB	1.15	-	-	1.50	0.90
42	☒	LG278 .. 279	UB	1.15	-	-	-	1.50
43	☒	LG280 .. 293	UB	1.15	1.05	-	-	1.50
44	☒	LG294 .. 307	UB	1.15	1.05	1.05	-	1.50
45	☒	LG308 .. 321	UB	1.15	1.05	1.05	1.05	1.50
46	☒	LG322 .. 335	UB	1.15	1.05	-	1.05	1.50
47	☒	LG336 .. 337	UB	1.15	-	1.05	-	1.50
48	☒	LG338 .. 339	UB	1.15	-	1.05	1.05	1.50
49	☒	LG340 .. 341	UB	1.15	-	-	1.05	1.50

Figure 5.20: Mask 1.2 *Load Groups by Actions*

A: Literature

[1] DIN 1055-100 Actions on Structures. Edition March 2001

[2] DIN 18 800 Steel Constructions. Edition November 1990

[3] EN 1990 Basis of Structural Design

[4] Grünberg, J.: Basis of Structural Design – Principles of Safety and Design Rules for Structural Engineering. Commentary on DIN 1055-100, Edition 2004 (*German*)