Engineering Software
Dlubal

Version
November 2009

Add-on Module

RSCOMBI

Generation of Load Groups and Load Combinations

Program Description

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1. Introduction

1.1 Add-on Module RSCOMBI

Dear users of the add-on module RSCOMBI,

a new generation of standards requires checking various combinations of load cases. If you are working with more extensive spatial structures, the manual creation of all combinations can be very time-consuming and error-prone. With the add-on module RSCOMBI from the RSTAB program family, you can automate this creation process. During the development of the RSCOMBI module, we concentrated mainly on quality and user-friendliness.

RSCOMBI creates load groups and load combinations according to European standards and other country codes. The following standards are supported:

- EN 1990 [1], including relevant National Annexes (Eurocode)
- EN 1995 (Eurocode 5) [2]
- ASCE 7 (United States) [3]
- ACI 318-08 (United States) [4]
- CAN / CSA (Canada) [5]
- IS 800 (India) [6]
- DIN 1055-100 (Germany) [7]
- DIN 18800 (Germany) [8]
- DIN 1052 (Germany) [9]

RSCOMBI takes over load cases created in the main program RSTAB, assigns them corresponding actions in compliance with standards, and creates all possible load groups or load combinations according to the selected standard. Consequently, these groups and combinations are again transferred to RSTAB, where you can calculate them in the familiar way.

Often it is not necessary to transfer all generated load groups or combinations to RSTAB. You can reduce their number before the export automatically or manually. Thus, the calculation time is shortened.

RSCOMBI also offers the following functions:

- generation of load groups from RSTAB load cases for the non-linear analysis (including imperfections)
- generation of load combinations from RSTAB load cases for the linear analysis
- load cases can be defined as "alternative" (that is mutually exclusive)
- possibility to define dependence of load cases including imperfections on normal load cases
- besides default coefficients according to standards, you can define your coefficients and save them
- results are displayed in two ways:
  - *results by actions* correspond to a definition in relevant standards and make the check easier
  - *results by load cases* correspond to load groups and load combinations in the *Data* navigator of RSTAB
- a synoptic summary of results, including applied coefficients and information about actions and load cases
- reduction of a number of generated load groups by using the default analysis of extreme values for linear analysis results

We welcome any improvement suggestions by our users coming out from practice and wish you much success and delight when working with our module RSCOMBI.

Your DLUBAL ENGINEERING SOFTWARE team.

1.2 RSCOMBI Team

The following people participated in the development of the RSCOMBI module:

Program Coordinators

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

Programmer

- Mgr. Jaroslav Krul

Testing, Manuals and Support

- Ing. Vladimír Pátý
- Bc. Tibor Tóth
- Milan Tobolka
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- Mgr. Petra Pokorná
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- Mgr. Michaela Kryšková

1.3 Note to Manual

This manual is divided into several chapters, where the module is described from various important viewpoints. We assume that you know theoretical principles of structural loading according to relevant standards and all the appropriate problems. Nevertheless, this manual contains some theoretical information that facilitates better understanding of our module.

Here you can find a brief overview of chapters and annexes of this manual:

- **Chapter 1: Introduction**
  We briefly describe a functional range and usage options of the RSCOMBI module.
- **Chapter 2: Theoretical Principles**
  We shortly explain the theoretical principles of the RSCOMBI module. We mention rules and excerpts from the standards EN 1990, DIN 1055-100, and DIN 18800, because the module generates load groups and load combinations according to these norms. In this chapter, we also deal with a possibility to reduce generated results by using the default analysis of extreme values for linear calculation results.
- **Chapter 3: Using RSCOMBI Module**
  We describe work with RSCOMBI in detail. We explain selection of design cases, takeover of load cases from the main program RSTAB, allocation of load cases to actions and classification of actions to given categories. In addition, we describe how to define and save your own partial coefficients and combination coefficients. In this chapter, we also introduce view options for results and clarify export of generated load groups and load combinations to RSTAB.
- **Chapter 4: Examples**
- We give some examples in this chapter.

1.4 Installation

RSCOMBI is not a stand-alone program; it represents the add-on module integrated to the main program RSTAB. Therefore you have to start the installation of the RSTAB program to install RSCOMBI. During the installation, you must use a new authorization file that you got when purchasing the module. The installation process is described in the RSTAB manual.

2. Theoretical Principles

2.1 General

If you proceed according to new standards, often it can be very laborious to consider all possible load cases and to select the decisive ones.

The task for RSCOMBI is to compose automatically all potential load groups or load combinations according to the relevant standard.

The RSCOMBI module is integrated to the RSTAB program and it uses load cases that have been defined in the main program. RSCOMBI distinguishes between two categories during the transfer of load cases: The first category consists of normal load cases, the second one of load cases with imperfections. For working with load cases in RSCOMBI, it is not important whether the load cases from the first category are described in RSTAB as 'permanent', 'variable' or 'accidental', as 'prestress' or 'favorable'.

The standards set the rules that describe the combinations for independent actions in corresponding design situations. According to [9], an independent action occurs when characteristic values of a force or deformation have a unique origin (for example dead load, live load, snow or ice load, wind load or temperature actions). The actions are independent when they arise from different sources and a mutual relation can be neglected regarding structural safety.

In the RSCOMBI module, you can define the actions and then assign RSTAB load cases to those actions. Finally, the actions are classified into action categories according to the corresponding standards.

2.2 Standards

2.2.1 DIN 1055-100

The standard DIN 1055-100 [7] requires the ultimate limit state design and the serviceability limit state design.

The ultimate limit states include the

- loss of a static equilibrium of a structure or its part,
- failure of a structure or its part, for example by breakage, excessive deformation, transition to a kinematic chain, stability loss or shear,
- failure of a structure or its part due to material fatigue or other time-dependent actions.

The **ultimate limit states** should be analyzed in four design situations. Combination rules are set for these design situations:

- Permanent situations that correspond to regular conditions of structure operation
- Temporary situations that are related to time limited structural states, for example during construction or reparation

  The load combination for permanent and temporary situations (the basic combination) is:

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

  Formula 2.1

- Accidental situations that are related to accidental loads of a structure or its surroundings, for example fire, explosion or shock

  The load combination for accidental design situations is:

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

  Formula 2.2

- Seismic design situations

  The load combination for seismic design situations is:

$$\sum_{j\geq 1} G_{k,j} + P_k + \gamma_1 \cdot A_{Ed} + \sum_{i\geq 1} \psi_{2,i} \cdot Q_{k,i}$$

  Formula 2.3

Symbols in formulas:

$+$	"in combination with"
Σ	"combination of independent loads from"
$G_{k,j}$	independent permanent load that takes one or several characteristic constant values of force or deformation
P_k	independent load from prestress (characteristic prestress value)
$Q_{k,1}$	main independent variable load that takes one or several characteristic variable values of force or deformation
$Q_{k,i}$	secondary independent variable load that takes one or several characteristic variable values of force or deformation
A_d	design value of accidental load
A_{Ed}	design value of seismic load
$\gamma_{G,j}$	partial coefficient of permanent independent load $G_{k,j}$
$\gamma_{GA,j}$	like $\gamma_{G,j}$, but for accidental design situations
γ_P	partial coefficient of independent load from prestress
γ_{PA}	like γ_P, but for accidental design situations
$\gamma_{Q,1}$	partial coefficient of main independent variable load $Q_{k,1}$
$\gamma_{Q,i}$	partial coefficient of secondary independent variable load $Q_{k,i}$
γ_I	weight coefficient for seismic loads
Ψ	corresponding combination coefficient to determine representative values of variable loads

The **serviceability limit states** should be analyzed in three design situations. The following load combinations are set for these design situations:

- Characteristic situations with irreversible effects on a structure

  The load combination for characteristic situations is:

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

  Formula 2.4

- Frequent situations with reversible effects on a structure

  The load combination for frequent situations is:

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

  Formula 2.5

- Quasi-permanent situations with long-term effects on a structure

  The load combination for quasi-permanent situations is:

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

  Formula 2.6

The symbols are described on the previous page.

2.2.2 DIN 18800

The standard DIN 18800 [8] requires the ultimate limit state design and the serviceability limit state design.

The **ultimate limit states** are considered in two design situations. It is necessary to create basic combinations and accidental combinations.

Basic combinations:

- Permanent loads G and all unfavorable variable loads Q_i

  The load combination is:

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

  Formula 2.7

- Permanent loads G and always one unfavorable variable load Q_i

  The load combination is:

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

  Formula 2.8

Accidental combinations:

- Permanent loads G, all unfavorable variable loads Q_i and one accidental load A

  The load combination is:

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

  Formula 2.9

Symbols in formulas:

$+$	"in combination with"
Σ	"combination of independent loads from"
$G_{k,j}$	independent permanent load that takes one or several characteristic constant values of force or deformation
$Q_{k,i}$	independent variable load that takes one or several characteristic variable values of force or deformation
$A_{k,i}$	independent accidental load that takes one or several characteristic variable values of force or deformation
$\gamma_{G,j}$	partial coefficient of permanent independent load $G_{k,j}$
$\gamma_{Q,j}$	partial coefficient of independent variable load $Q_{k,1}$
$\gamma_{A,i}$	partial coefficient of independent accidental load $A_{k,i}$
$\gamma_{GA,j}$	like $\gamma_{G,j}$, but for accidental design situations
Ψ	relevant combination coefficient to determine representative values of variable loads

2.2.3 EN 1990

The standard EN 1990 [1] requires the ultimate limit state design and the serviceability limit state design.

The ultimate limit states include:

- **EQU**: Loss of a static equilibrium of a structure or its part, where
  - even smaller variations in a load value or spatial distribution of load of the same origin are important
  - strength of structural materials or of foundation soil is usually not decisive.
- **STR**: An inner failure or excessive deformation of a structure or supporting elements including foundation footings, piles, underground walls and so on, where the strength of structural materials is decisive.
- **GEO**: A failure or excessive deformation of foundation soil, where the strength of soil or rock subsoil are important for the ultimate limit state.
- **FAT**: A fatigue failure of a structure or supporting elements.

The **ultimate limit states** should be analyzed in four design situations. Combination rules are stated for these design situations:

- Permanent situations that correspond to conditions of regular structure operation
- Temporary situations that are related to time-limited states of a structure, for example during construction or reparation

  The load combination for permanent and temporary situations (the basic combination) is either according to the formula

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

  Formula 2.10

  or, alternatively for STR and GEO limit state, as a less favorable combination from formulas 2.11 and 2.12:

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

  Formula 2.11

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

  Formula 2.12

- Accidental situations that are related to accidental loads of a structure or its surroundings, for example fire, explosion or shock

  The load combination for accidental design situations:

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

  Formula 2.13

- Seismic design situations

  The load combination for seismic design situations is:

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

  Formula 2.14

Formula 2.12 contains the reduction coefficient for unfavorable permanent loads ξ_j. The other symbols have their common meanings (see page 7).

The **serviceability limit states** should be analyzed in three design situations that are the same like in the standard DIN 1055-100. For these design situations, the following load combinations are set:

- Characteristic situations with irreversible effects on a structure

  The load combination for characteristic situations:

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

  Formula 2.15

- Frequent situations with reversible effects on a structure

  The load combination for frequent situations:

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

  Formula 2.16

- Quasi-permanent situations with long-term effects on a structure

  The load combination for quasi-permanent situations:

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

  Formula 2.17

In the European standard EN 1990, the combination rules have been fixed. However, each state can alter the values of used coefficients. In RSCOMBI where you select the standard **EN 1990 CEN**, the coefficients set by European commission CEN will be applied.

2.3 Reducing Load Groups

The complexity of the structure and the number of loads and load cases influence the number of generated load groups or load combinations considerably. If you apply the standards DIN 1055-100 or EN 1990 in particular, you get often a very high number of load groups.

The RSCOMBI module offers the option to reduce the number of possible load groups effectively and to generate only decisive groups of load cases.

For this, one or more load combinations are generated automatically. Those are then calculated in the main program RSTAB. The number of load combinations depends on the selected design situation.

For every x-location, it is checked if the load case induces any maximum or minimum value. Only those load cases are used in RSCOMBI to form load groups or load combinations.

The reduction by using automatically generated combinations guarantees that the results in RSCOMBI will contain all decisive groups of load cases. Instead of automatically generated combinations, you can also create your own load combinations in RSTAB for this reduction and use them in RSCOMBI. A reduction of this kind does not differ functionally from an automated reduction by generated load combinations.

The reducing option is only possible for creating load groups, not for load combinations.

3. Using RSCOMBI

3.1 Starting RSCOMBI

The RSCOMBI module can be started by using the command from the main menu **Additional Modules** → **Others** → **RSCOMBI 2006** or from the *Data* navigator by clicking the item **Additional Modules** → **RSCOMBI 2006**.

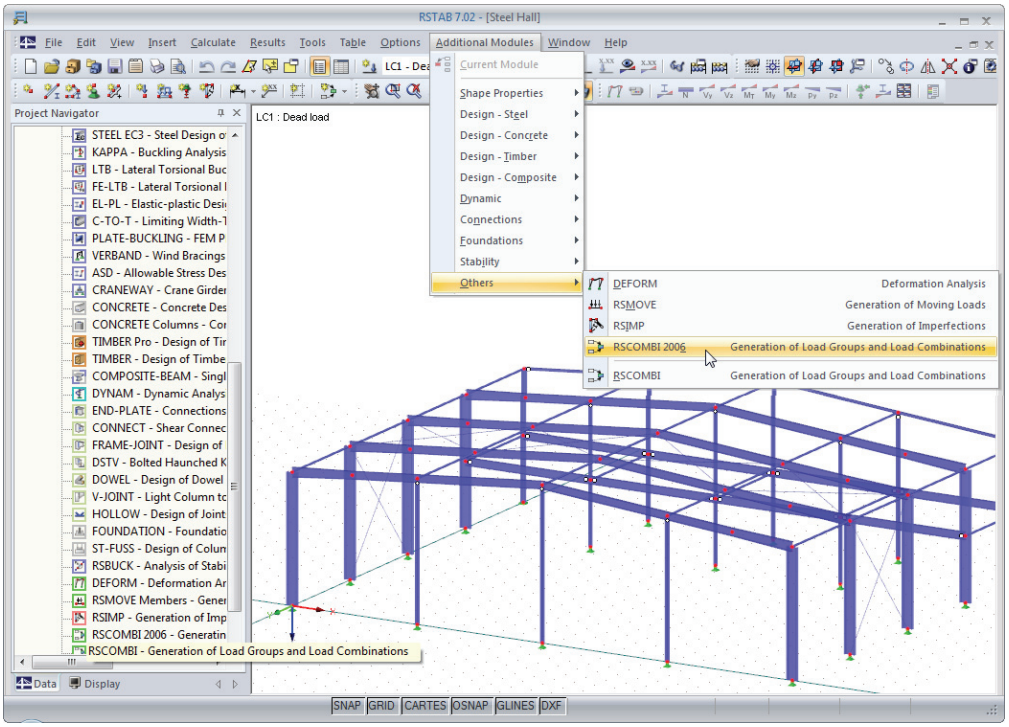

Figure 3.1: Starting the RSCOMBI module from the *Data* navigator and from the main menu *Additional Modules*

3.2 Masks

Masks are used to enter input data and to define cases in RSCOMBI and also later to display numeric results on a screen.

After RSCOMBI has been started, you can see the navigator on the left side that contains all currently available masks. Above the navigator, there is the list of previously defined cases.

You can open the masks either by clicking the relevant navigator item in RSCOMBI or you can browse them by using the keys [F2] and [F3] or the buttons [⇐] and [⇒].

By using the [Calculation] button, you run the generation procedure after having defined of all input data.

By the [OK] button, you save both input data and results before you exit the module, while by the button [Cancel] you exit the module without data saving.

By the [?] button or the functional key [F1], you start the *Help* function.

By the [Coefficients...], you open the dialog box, where you can define partial safety coefficients or combination coefficients.

By the [Check] button, you can run the plausibility check.

The buttons [Calculation], [Coefficients...], and [Check] are available only in input masks.

If any results mask is opened after a successful calculation, the [Export...] button is available in that mask. By using this button, you can export the generated load groups or load combinations to the main program RSTAB.

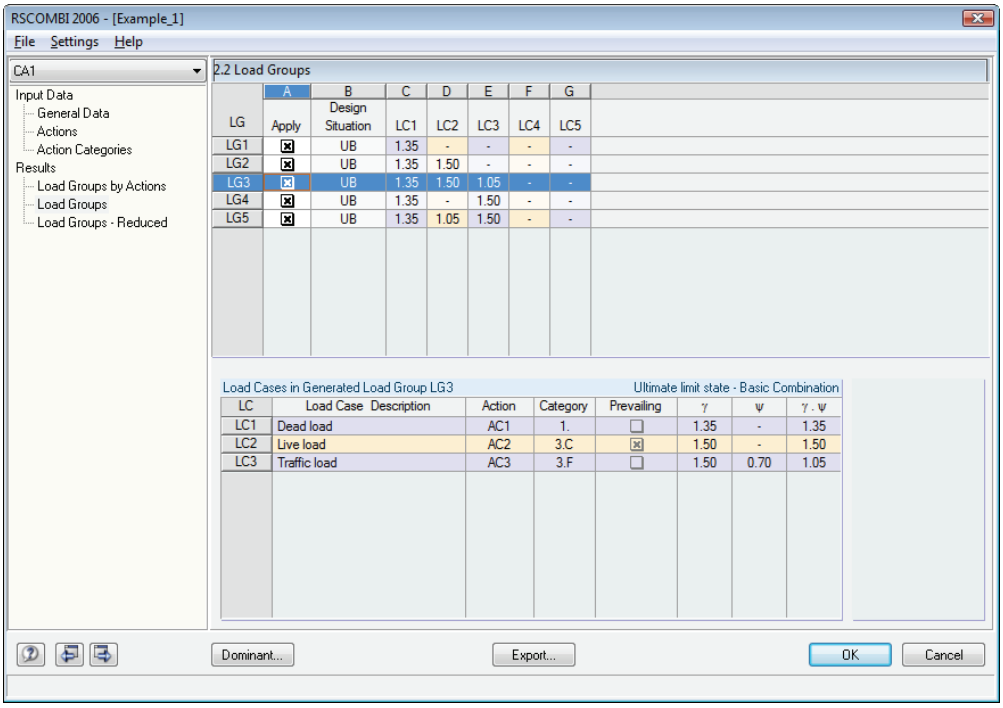

Figure 3.2: Basic layout of results masks

3.3 Input Masks

In the input masks, all data and parameters necessary for the generation are entered.

3.3.1 Load Combinations According to DIN 1055-100

3.3.1.1 General Data

After having started RSCOMBI, the mask 1.1 *General Data* appears in the module window.

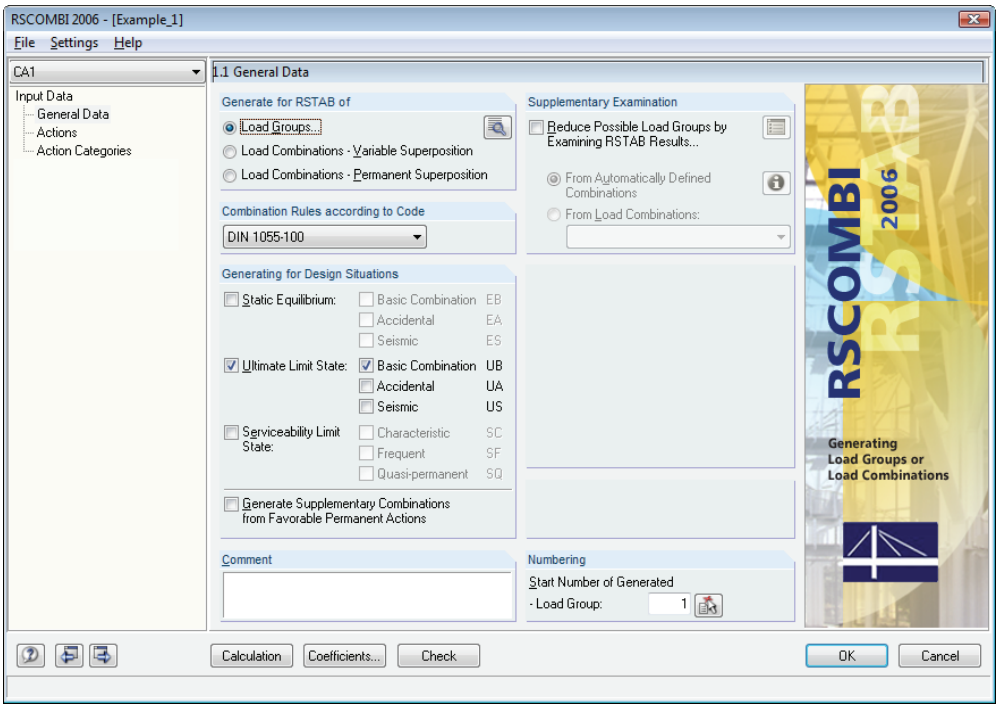

Figure 3.3: Mask 1.1 *General Data*

In the section *Generate for RSTAB*, you can decide if *Load groups* or *Load combinations* from variable or permanent load cases are to be generated. The difference between load groups and load combinations is described in detail in the RSTAB manual. If you select the option *Load combinations – permanent superposition*, all load cases with the attribute "permanent" are considered. In this case, a considerably greater number of load combinations will be generated than with the variable superposition.

In the section *Combination Rules According to Code*, you choose the standard and, thus, also the rules how to generate load groups or load combinations. The following standards are available: EN 1990, EN 1995, ASCE 7, ACI 318-08, CAN/CSA, IS 800, DIN 1055-100, DIN 18800, and also DIN 1052. The following description in this chapter is related to the standard DIN 1055-100.

The standard DIN 1055-100 requires the ultimate limit state design and the serviceability limit state design. For the ultimate limit state, it is distinguished whether loss of a static equilibrium or failure by breakage are considered. With the module, you can generate load combinations for the following *Design Situations*:

- Static equilibrium (ultimate limit state, partial coefficients for the analysis of static loss of equilibrium)
  - Basic combination – see formula 2.1
  - Accidental – see formula 2.2
  - Seismic – see formula 2.3

- Load capacity (ultimate limit state, partial coefficients for the analysis of a structure failure by breakage)
  - Basic combination – see formula 2.1
  - Accidental – see formula 2.2
  - Seismic – see formula 2.3
- Analysis of serviceability (serviceability limit state)
  - Characteristic – see formula 2.4
  - Frequent – see formula 2.5
  - Quasi-permanent – see formula 2.6

If you tick the option *Generate supplementary combinations from favorable permanent actions*, the favorable and unfavorable actions will be considered separately. They enter the analysis with different partial coefficients. However, this is related only to the design situation 'Ultimate limit state'. In case of the design situation 'Static equilibrium', these actions are always distinguished, while the design situation 'Serviceability' does not recognize favorable and unfavorable actions.

In the section *Supplementary Examination*, you can select *Reduce possible load groups by examining RSTAB results...* Then you have to decide if automatically generated combinations will be calculated in RSTAB or other combinations will be selected for calculation. These combinations must be predefined in RSTAB, though. The principle of this reduction is described in chapter 2.3.

In the section *Numbering*, you can enter the first number of the generated load group or load combination which is created in RSTAB after the export. If you click the button next to the input box, the first free number is set for the generated load group or combination.

3.3.1.2 Actions

In mask 1.2 *Actions*, actions are created and load cases that have been defined in RSTAB are assigned to them. This mask is divided into the sections *Actions, Existing Load Cases*, and *Load Cases in Action AC#*.

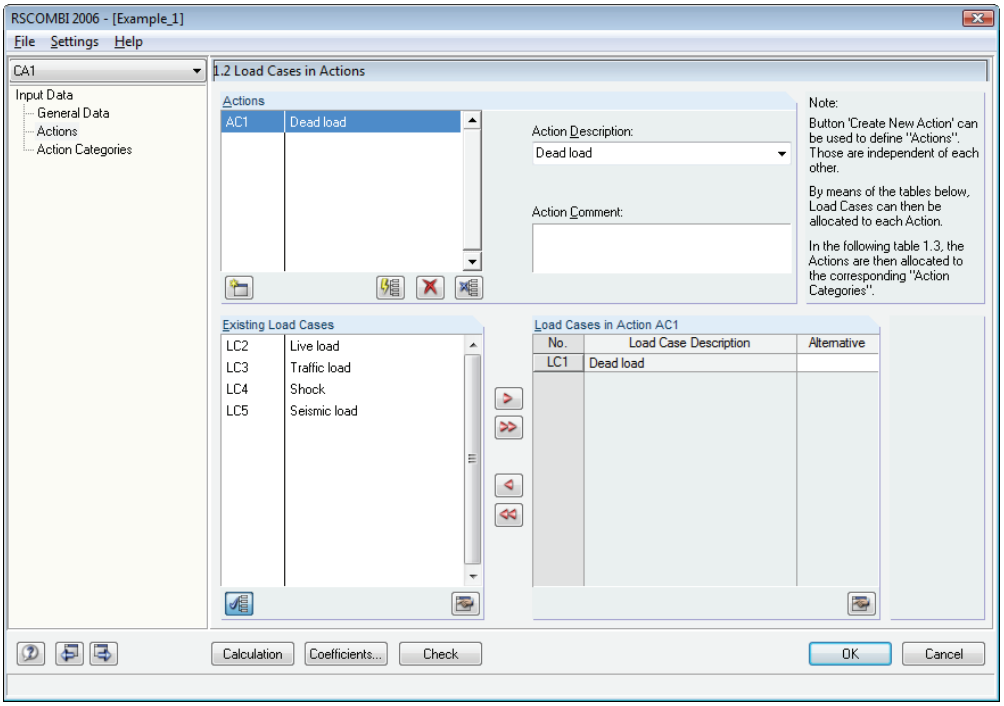

Figure 3.4: Mask 1.2 *Actions*

In the section *Actions*, the list of all already created actions is displayed. The actions can be specified by *Action description* or by *Action comment*.

A new action is created by using the button in the section *Actions*, in the bottom left corner.

By the second button, you create a number of new actions that is equal to the number of load cases. Consequently, exactly one load case is allocated to every action.

By the next button, you delete a selected action.

With the last button, you can delete all actions created so far.

In the section *Existing Load Cases*, you can see the list of all load cases taken over from RSTAB which have not yet been allocated to any action. The list does not contain the RSTAB load cases defined as 'Imperfections'.

If you select the button in the bottom left corner in the section *Existing Load Cases*, all load cases that have not been allocated yet are displayed in the list. If this button is not selected, all load cases are displayed.

The second button in this section is used to edit the General Data of a selected load case.

The list of load cases that are allocated to a currently selected action is shown in the section *Load Cases in Action AC#*. You can assign either only one selected load case or all existing load cases together. Each load case can be allocated to one action only. With the button in the bottom right corner of the section *Load Cases in Action AC#*, you can edit the General Data of the selected load case.

Two or even more load cases can be defined as mutually exclusive ones. It means that these cases never occur in a load group or load combination simultaneously. This can be achieved by entering the same description for these load cases in the *Alternative* column.

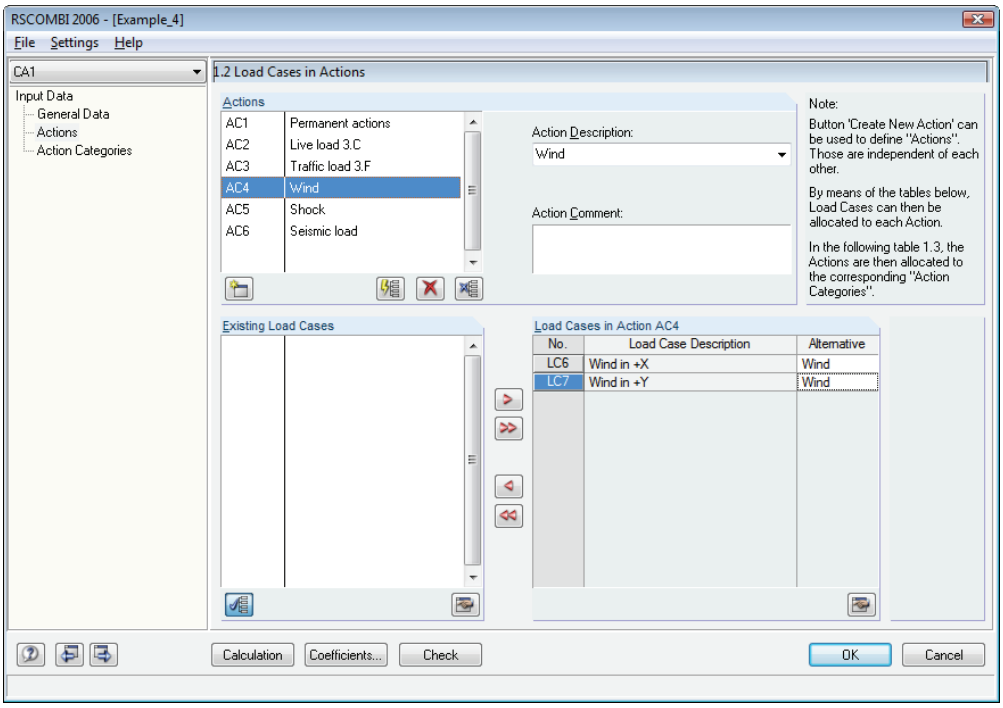

Figure 3.5: Alternative relation between LC6 and LC7

3.3.1.3 Action Categories

In the mask 1.3 *Action Categories*, the actions are allocated to the relevant categories.

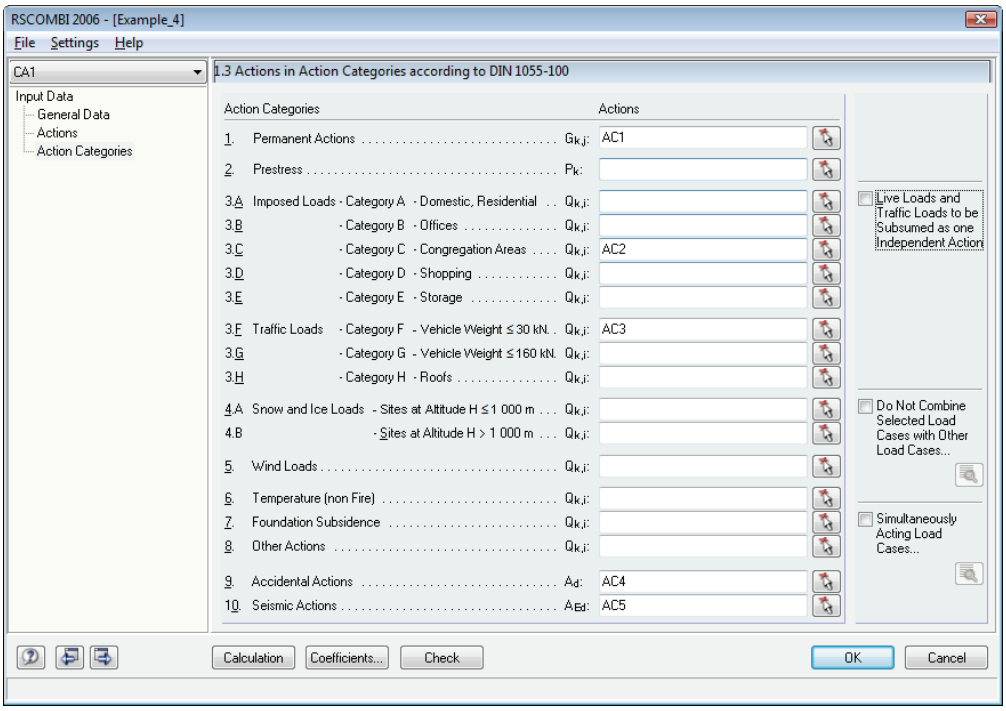

Figure 3.6: Mask 1.3 *Action Categories*

To allocate actions to specific categories, the *Actions* are to be selected in the relevant entry fields. You can also use the button [Select action(s) from a list] which opens the dialog box *Select Actions*. There, a list of all actions that have not been allocated yet is shown.

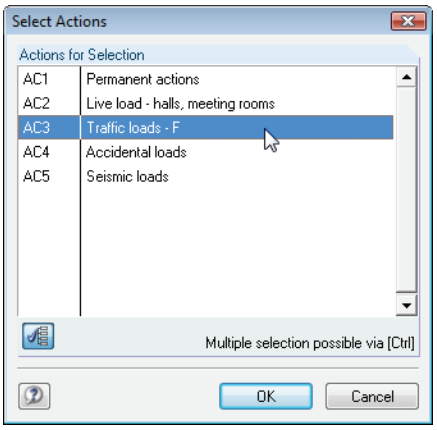

Figure 3.7: Dialog box *Select Actions*

In mask 1.3, you can use the option *Live loads and traffic loads to be subsumed as one independent action*. The possibility to merge live and traffic loads that exist within one building is explained for example in [9], annex A, page 37. This option influences the generation of load groups or load combinations according to formulas 2.1, 2.2, 2.4, and 2.5 (see chapter 2.2.1) which contain the main variable load $Q_{k,1}$. If you select this option, either all live and traffic loads will be considered as the main loads or none of them will be classified as main load. Thus, all live and traffic loads will be always multiplied by the same combination coefficient ψ.

3.3.1.4 Imperfections

The mask 1.4 *Imperfections* is only displayed if load groups are to be generated. Only load groups can be calculated according to a second order or large deformation analysis.

This mask contains the sections *Existing Load Cases - Type 'Imperfection'*, *Imperfection-Type Load Cases in Combinations*, and *Options*.

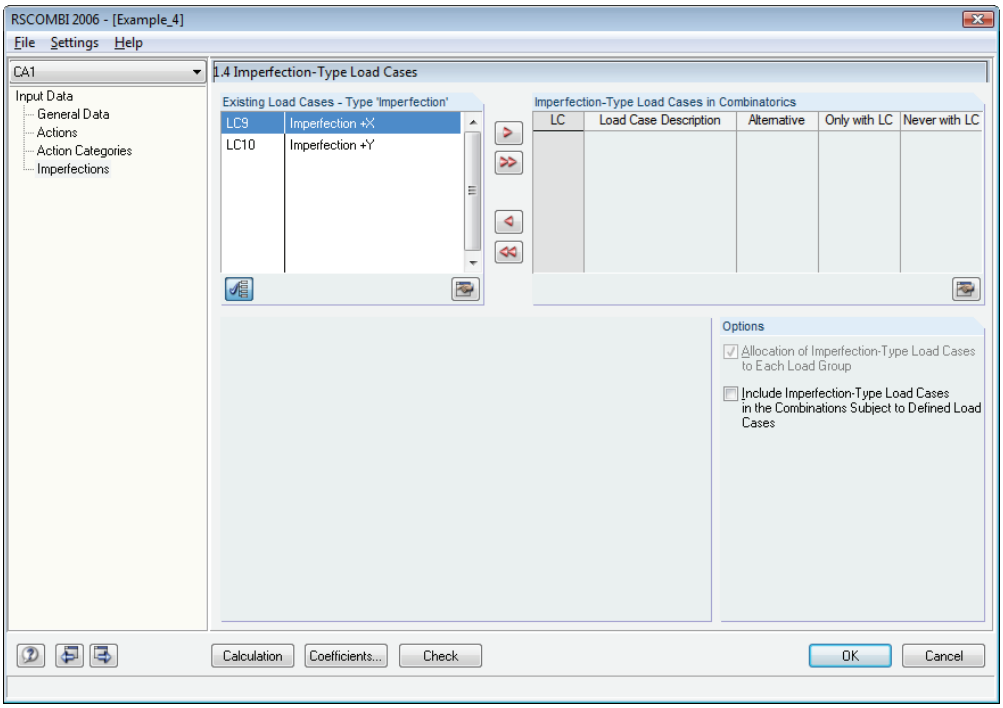

Figure 3.8: Mask 1.4 *Imperfections*

In the section *Existing Load Cases - Type 'Imperfection'*, all imperfections created in RSTAB which have not yet been put into groups for generation are displayed. The buttons in the sections have the same functions as in mask 1.2.

RSCOMBI takes into account only imperfections selected in the section *Imperfection-Type Load Cases in Combinations*.

If you have selected at least one imperfection-type load case, every possible load group will be created with and without those imperfections. If you want to generate only load cases with imperfections, it is necessary to tick the box *Allocation of imperfection-type load cases to each load group* in the section *Options*.

In Figure 3.9, the load cases LC9 and LC10 are to be used for the generation of load groups. At first, load groups without any imperfections will be generated, then with LC9, then with LC10, and finally with LC9 and LC10 simultaneously.

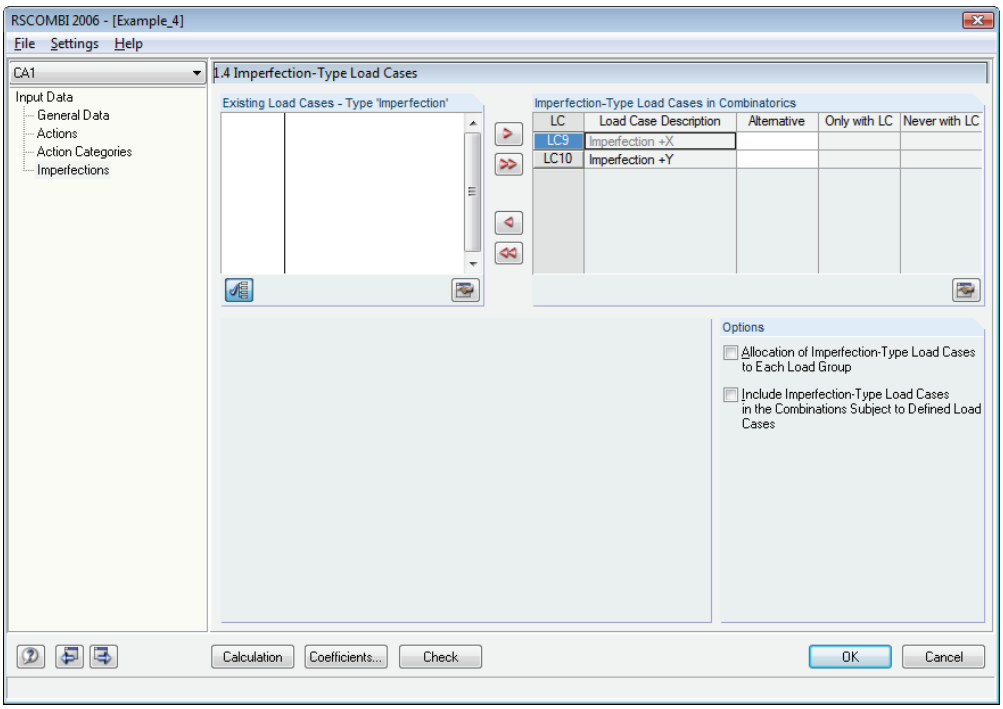

Figure 3.9: Mask 1.4 *Imperfections*, section *Imperfection-Type Load Cases in Combinations*

You can define the imperfection-type load cases as *Alternative*, similarly to ordinary load cases. Hence, only one imperfection-type load case is put into each load group.

In the columns *Only with LC* and *Never with LC*, you can further reduce the number of generated load groups. For this, select the option *Include imperfection-type load cases in the combinations subject to defined load cases* in the section *Options* below. In this way, you can determine the relation between the relevant imperfection and a specific load case.

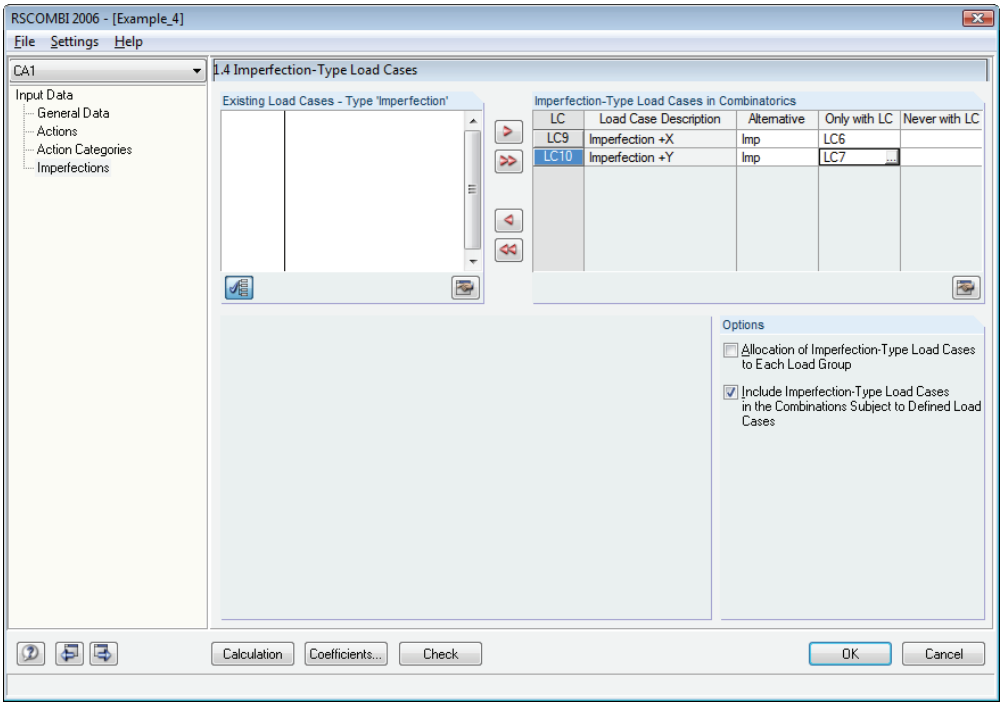

Figure 3.10: Mask 1.4 *Imperfections*, section *Options*

3.3.1.5 Coefficients

You open the dialog box *Coefficients* by clicking the button [Coefficients…]. This dialog box has two tabs.

In these tabs, the *Partial Safety Coefficients* and *Combination Coefficients* which will be used to generate load groups or combinations are set by default according to the standard DIN 1055-100.

In the tab *Partial Safety Coefficients*, the design situations for both the static equilibrium and ultimate limit state are defined. They only differ in the respective safety coefficients.

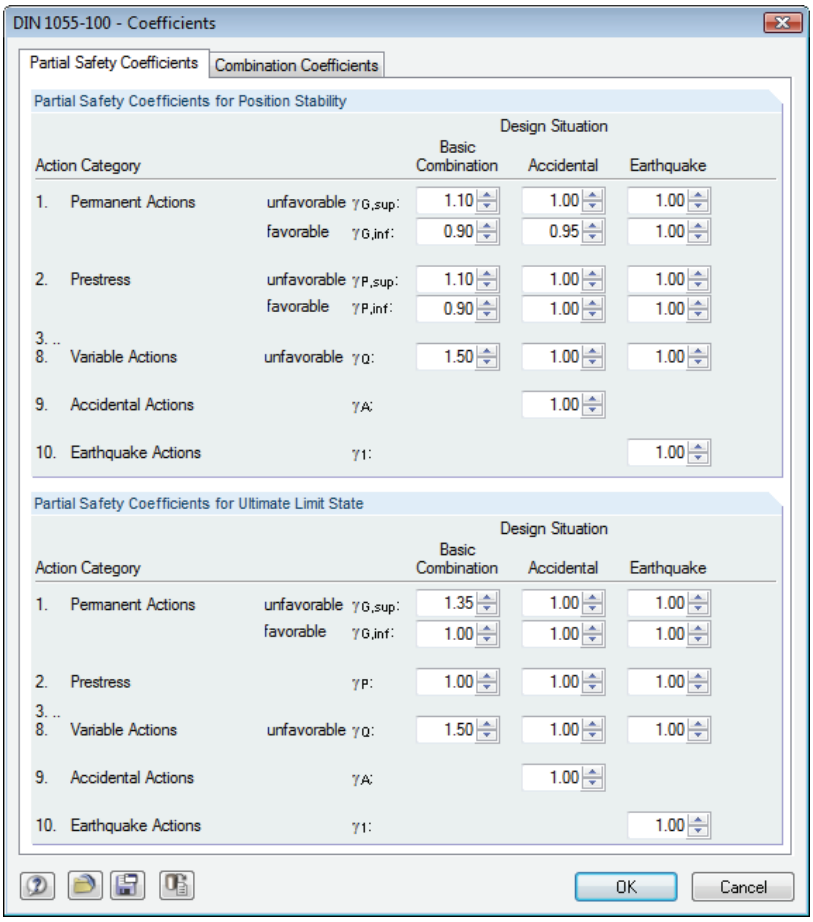

Figure 3.11: Dialog box *Coefficients*, default partial safety coefficients according to DIN 1055-100

The *Combination Coefficients* differ according to the action categories.

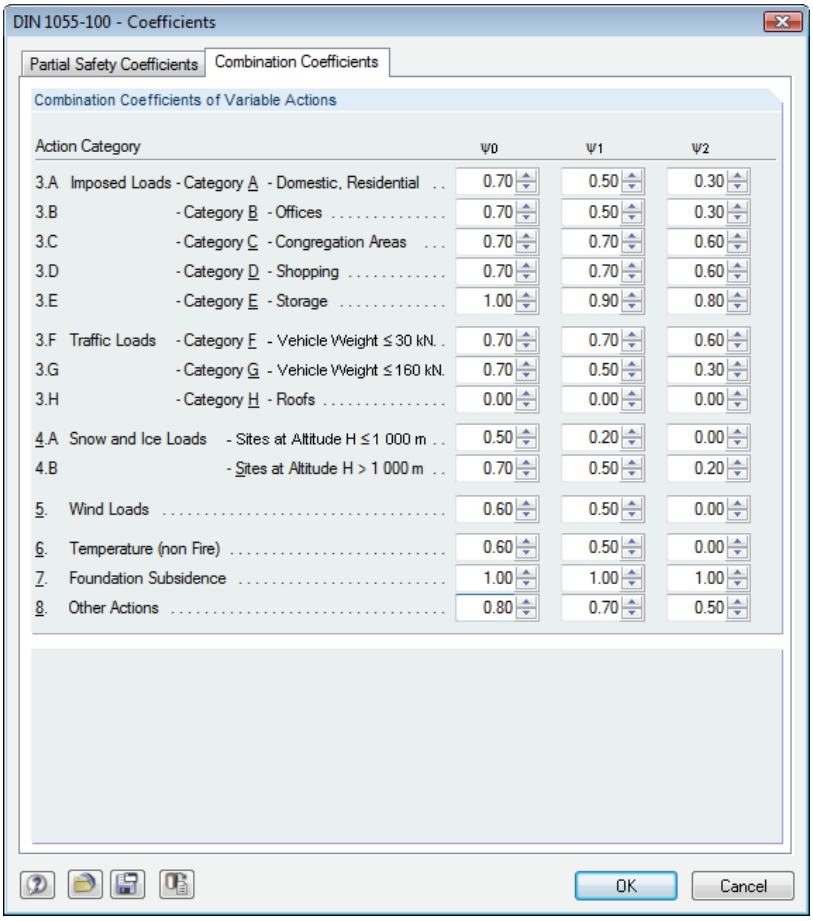

Figure 3.12: Dialog box *Coefficients*, default combination coefficients according to DIN 1055-100

Apart from the coefficients that are set by default according to corresponding standards, you can also create and save your own sets of coefficients. Click the button [Save Factors As 'Set of Coefficients'] to open a dialog box where you can enter a name of a new set.

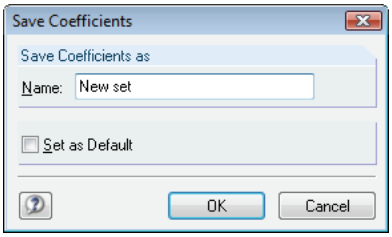

Figure 3.13: Dialog box *Save Coefficients*

You can set the new coefficients as default.

The button [Load Set of Coefficients] opens a dialog box where previously defined sets of coefficients can be loaded (see Figure 3.14 on the following page).

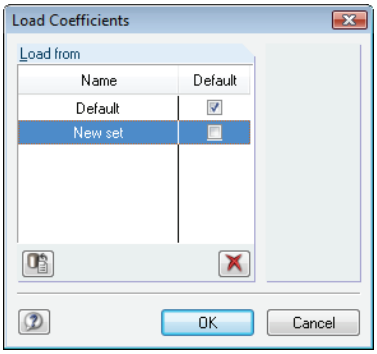

Figure 3.14: Dialog box *Load Coefficients*

The set of coefficients *Default*, corresponding to the standard, represents the first item in this list. You cannot edit or delete this set.

By using the check box next to the set name, you can also define a different set as default.

3.3.2 Load Combination According to DIN 18800

3.3.2.1 General Data

After having started RSCOMBI, the mask 1.1 *General Data* appears in the module window.

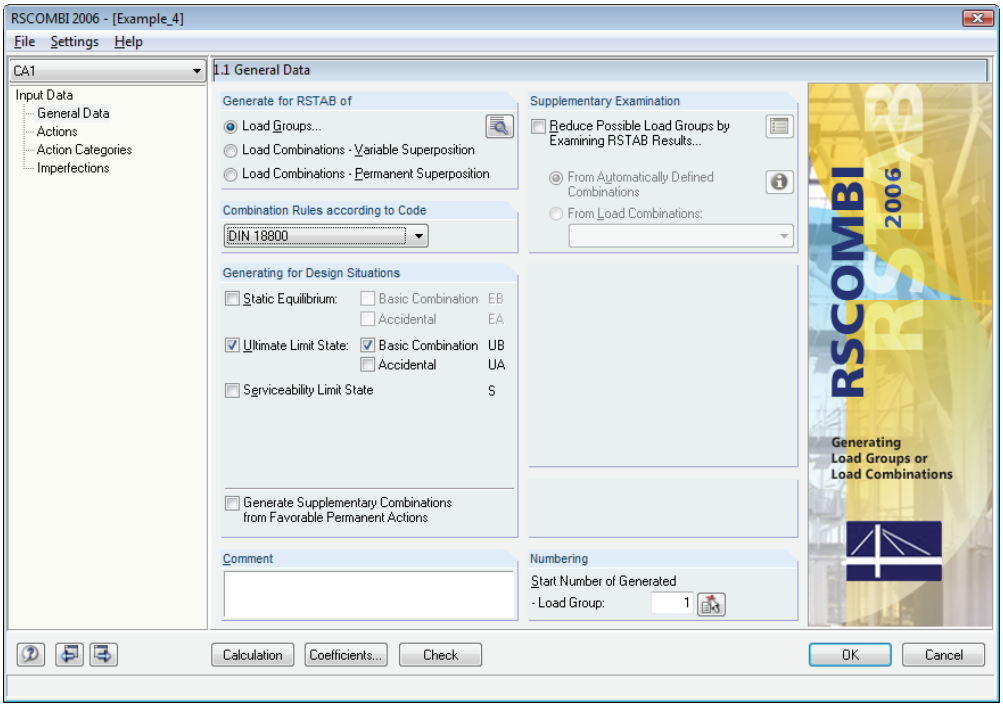

Figure 3.15: Mask 1.1 *General Data*

In this mask, only the section *Generation for Design Situations* is different from the mask described in chapter 3.3.1.1 on page 13.

The standard DIN 18800 requires the ultimate limit state design and the serviceability limit state design. For the ultimate limit state, it should be distinguished whether the loss of the static equilibrium or the failure due to breakage are considered. RSCOMBI enables you to generate load combinations for the following *Design Situations*:

- Static equilibrium (ultimate limit state, partial coefficients for criterion loss of static equilibrium)
  - Basic combination – see formula 2.7 and formula 2.8
  - Accidental – see formula 2.9
- Load capacity (ultimate limit state, partial coefficients for criterion failure of structure due to breakage)
  - Basic combination – see formula 2.7 and formula 2.8
  - Accidental – see formula 2.9
- Serviceability (serviceability limit state) – see formula 2.7

3.3.2.2 Actions

In this mask, actions are created and load cases that have been defined in RSTAB are assigned to them.

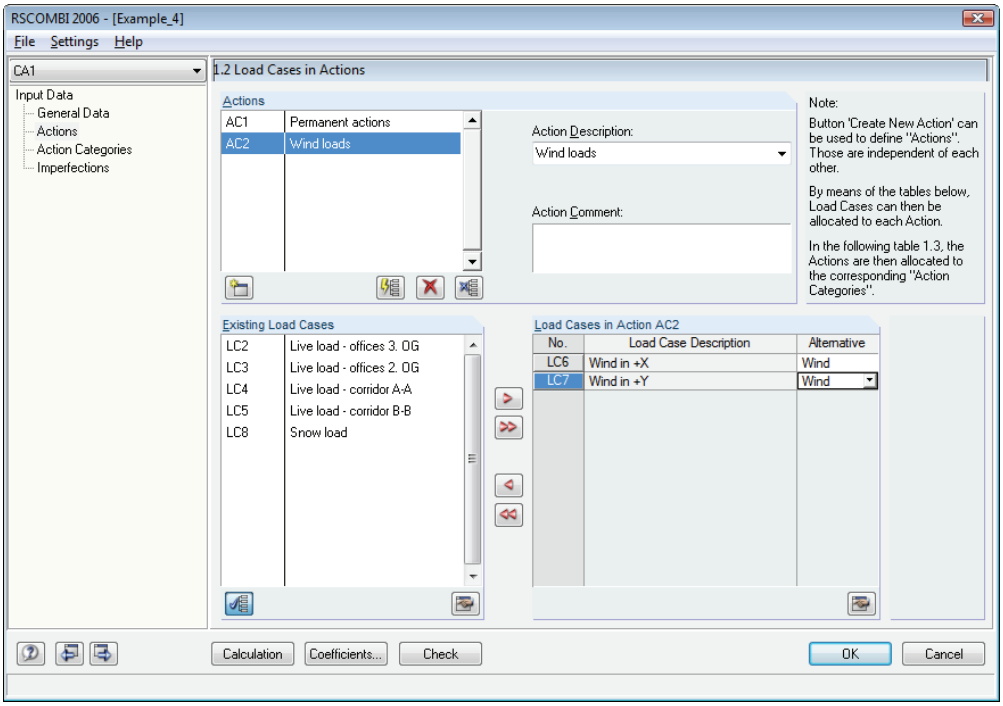

Figure 3.16: Mask 1.2 *Actions*

The functionality of this mask does not depend on the standard. All functions are described in chapter 3.3.1.2 on page 14.

3.3.2.3 Action Categories

In this mask, the actions are allocated to the relevant categories.

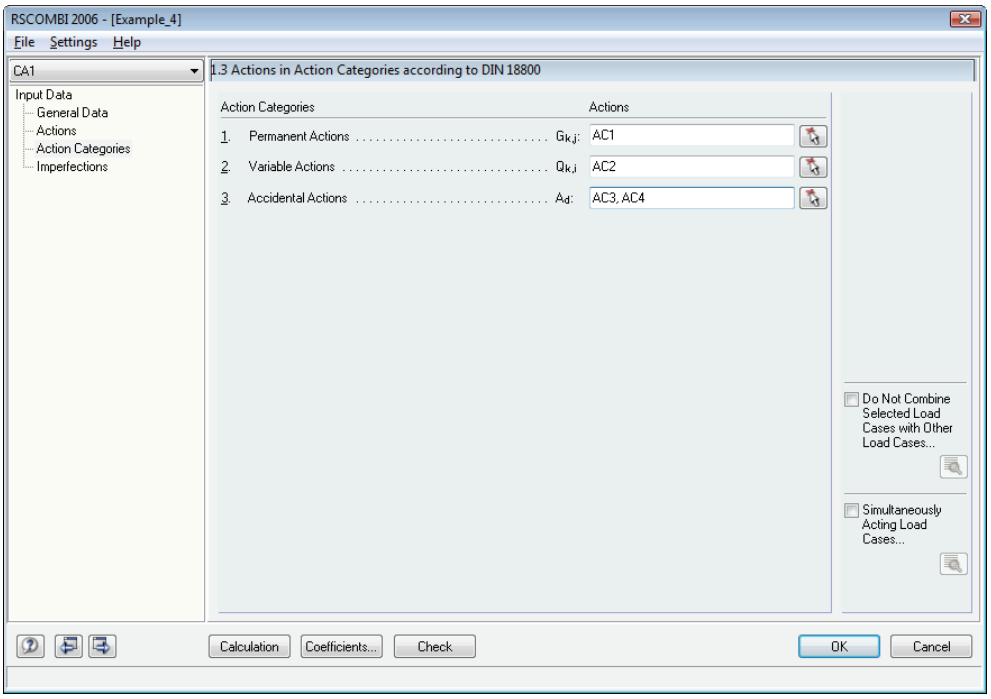

Figure 3.17: Mask 1.3 *Action Categories*

For DIN 18800, the assignment of actions to individual categories is the same like for the standard DIN 1055-100. It is described in chapter 3.3.1.3 on page 16.

3.3.2.4 Imperfections

The mask 1.4 *Imperfections* is only displayed if load groups are to be generated.

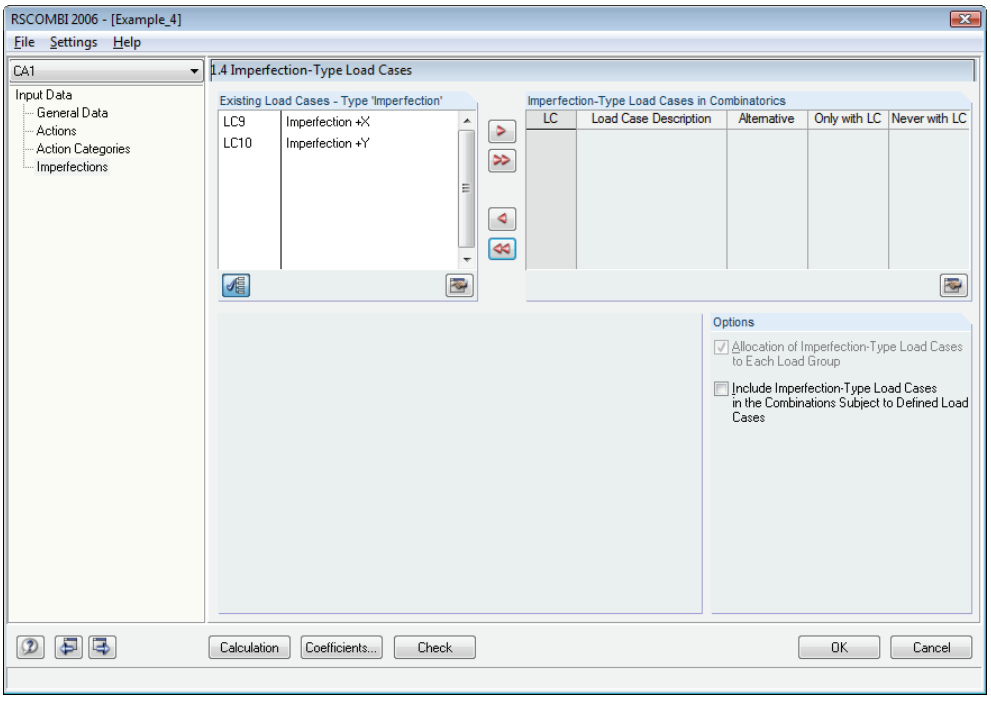

Figure 3.18: Mask 1.4 *Imperfections*

This mask contains the sections *Existing Load Cases - Type 'Imperfection'*, *Imperfection-Type Load Cases in Combinations*, and *Options*.

The functionality of this mask is independent of the selected standard. It is described in chapter 3.3.1.4 on page 17.

3.3.2.5 Coefficients

You open the dialog box *Coefficients* by clicking the button [Coefficients...]. The dialog box has two tabs.

In these tabs, the *Partial Safety Coefficients* and *Combination Coefficients* which will be used to generate load groups or combinations are set by default according to the standard DIN 18800.

In the tab *Partial Safety Coefficients*, the design situations for both the static equilibrium and ultimate limit state are defined. They only differ in the respective safety coefficients.

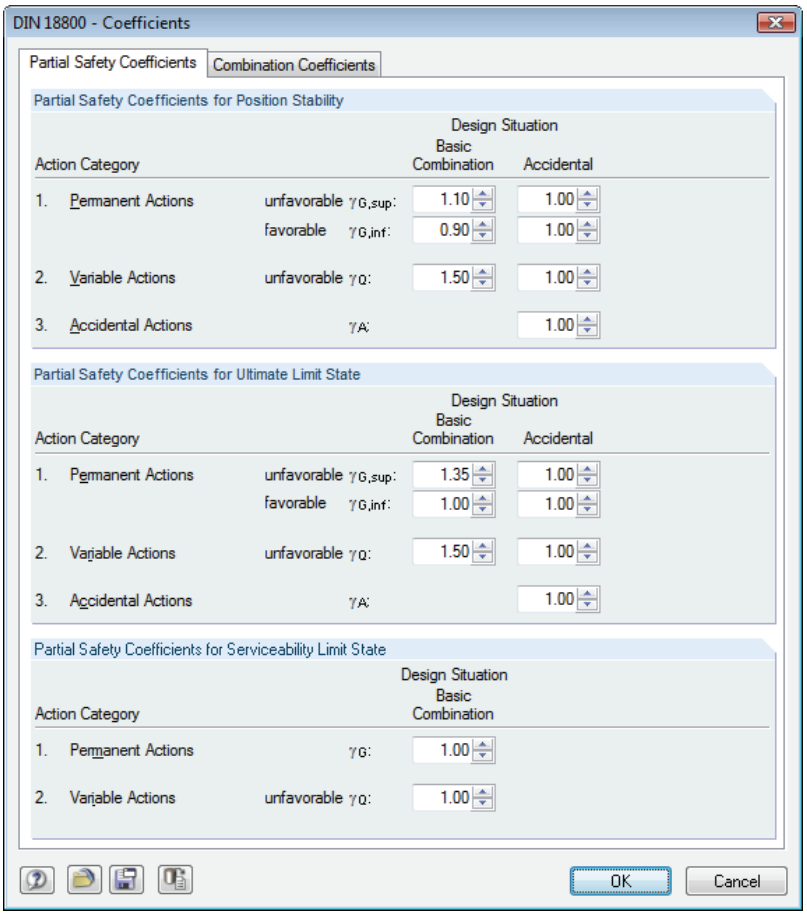

Figure 3.19: Dialog box *Coefficients*, default partial safety coefficients according to DIN 18800

The *Combination Coefficients* differ according to the design situations.

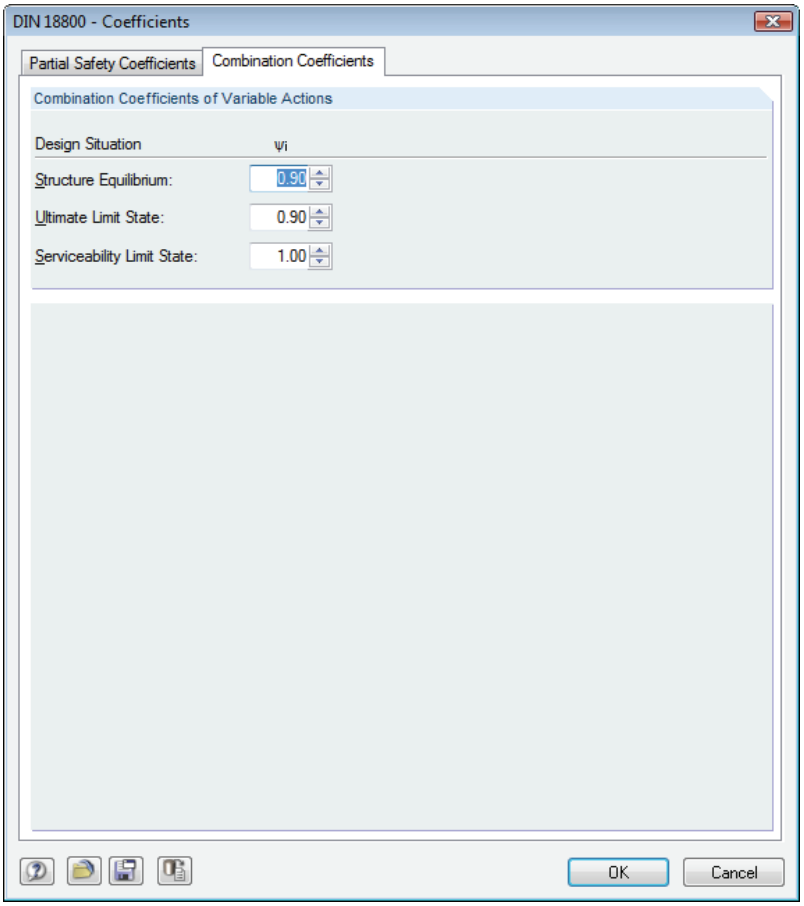

Figure 3.20: Dialog box *Coefficients*, default combination coefficients according to DIN 18800

Apart from the coefficients that are set by default according to corresponding standards, you can also create and save your own sets of coefficients (see chapter 3.3.1.5 on page 19).

3.3.3 Load Combination According to EN 1990

3.3.3.1 General Data

After having started RSCOMBI, the mask 1.1 *General Data* appears in the module window.

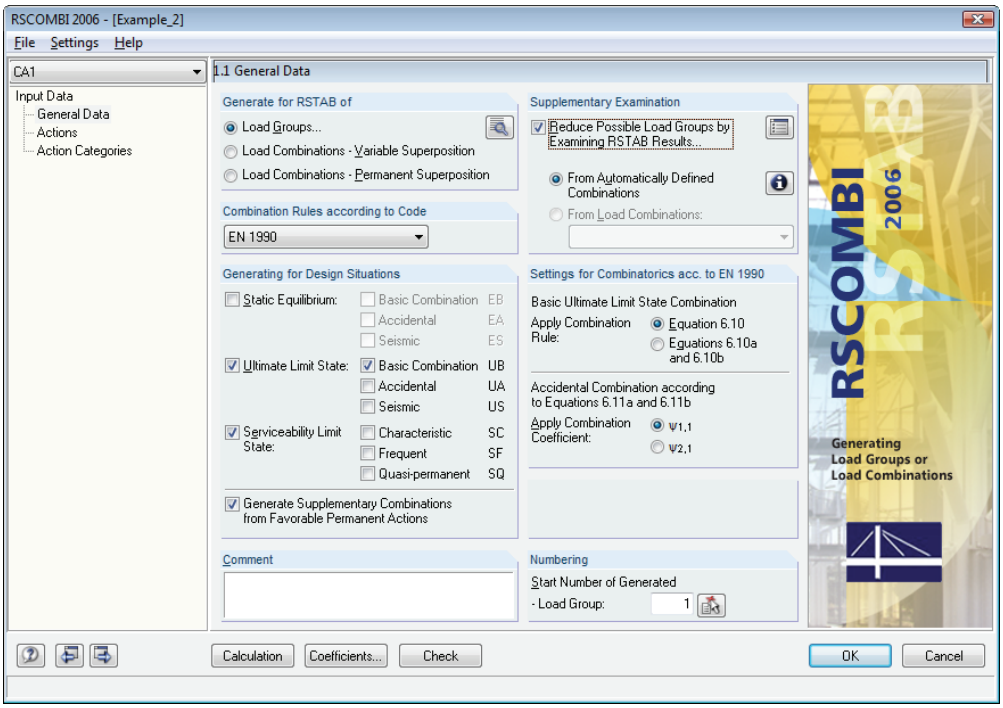

Figure 3.21: Mask 1.1 *General Data*

In this mask, only the section *Generation for Design Situations* is different from the mask described in chapter 3.3.1.1 on page 13.

The following description refers to the standard EN 1990. EN 1990 CEN or EN 1990 CZ only differ in the coefficients that are set by default.

The standard EN 1990 requires the ultimate limit state design and the serviceability limit state design. For the ultimate limit state, it should be distinguished whether the loss of the static equilibrium or the failure due to breakage are considered. RSCOMBI enables you to generate load combinations for the following *Design Situations*:

- Static equilibrium (ultimate limit state, partial coefficients for criterion loss of static equilibrium)
  - Basic combination – see formula 2.10, formula 2.11 or formula 2.12
  - Accidental – see formula 2.13
  - Seismic – see formula 2.14
- Load capacity (the ultimate limit state, partial coefficients for the analysis of a structure failure by breakage)
  - Basic combination – see formula 2.10, formula 2.11 or formula 2.12
  - Accidental – see formula 2.13
  - Seismic – see formula 2.14
- Serviceability (the serviceability limit state)
  - Characteristic – see formula 2.15
  - Frequent – see formula 2.16
  - Quasi-permanent – see formula 2.17

3.3.3.2 Actions

In this mask, actions are created and load cases that have been defined in RSTAB are assigned to them.

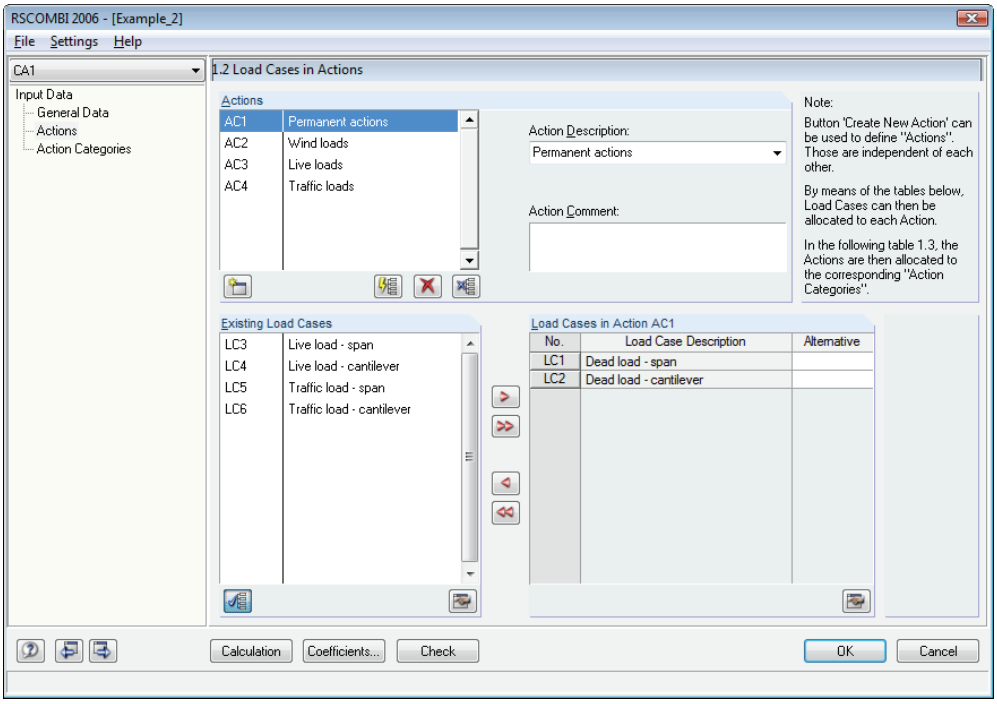

Figure 3.22: Mask 1.2 *Actions*

The functionality of this mask does not depend on the standard. All functions are described in chapter 3.3.1.2 on page 14.

3.3.3.3 Action Categories

In mask 1.3, the actions are allocated to the relevant categories.

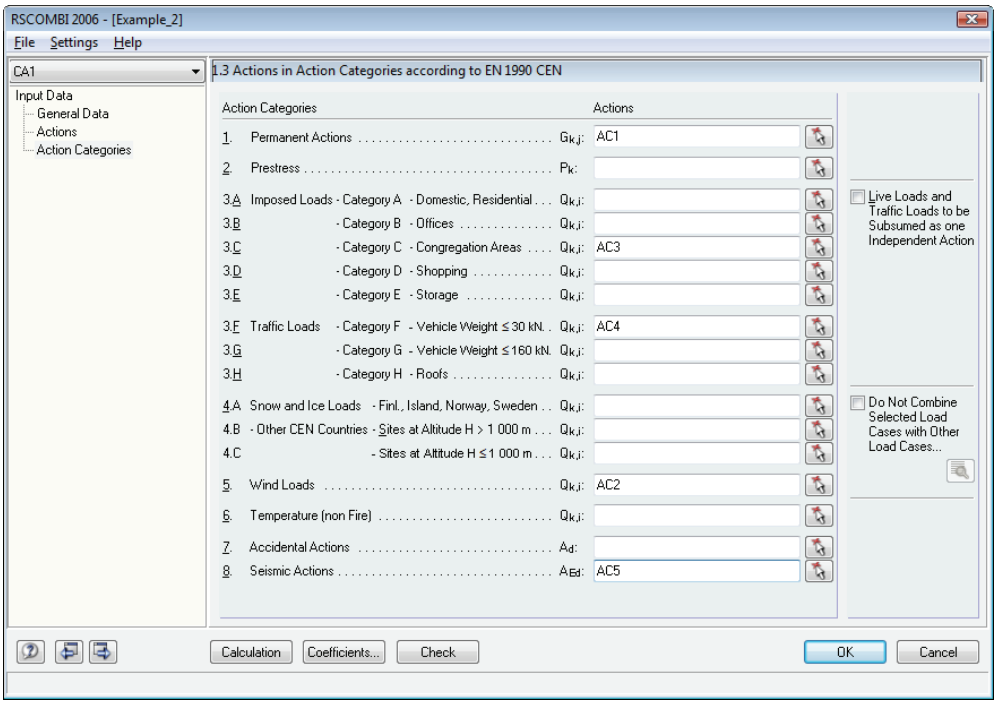

Figure 3.23: Mask 1.3 *Action Categories*

For EN 1990, the assignment of actions to individual categories is the same like for the standard DIN 1055-100 and is described in chapter 3.3.1.3 on page 16.

3.3.3.4 Imperfections

The mask 1.4 *Imperfections* is only displayed only if load groups are to be generated. Only load groups can be calculated according to the second order or large deformation analysis.

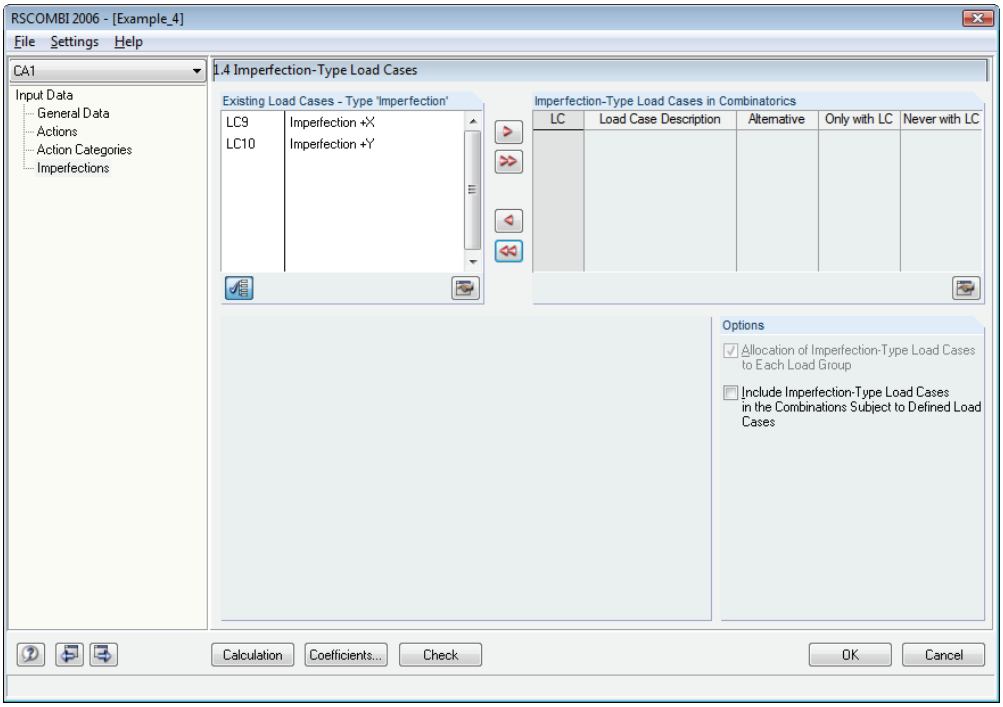

Figure 3.24: Mask 1.4 *Imperfections*

This mask contains the sections *Existing Load Cases - Type 'Imperfection'*, *Imperfection-Type Load Cases in Combinations*, and *Options*.

The functionality of this mask is independent of the selected standard. It is described in chapter 3.3.1.4 on page 17.

3.3.3.5 Coefficients

You open the dialog box *Coefficients* by clicking the button [Coefficients...]. The dialog box has two tabs.

In these tabs, the *Partial Safety Coefficients* and *Combination Coefficients* which will be used to generate load groups or combinations are set by default according to the standard EN 1990.

In the tab *Partial Safety Coefficients*, the design situation for both the static equilibrium and ultimate limit state are defined. They only differ in the respective partial safety coefficients.

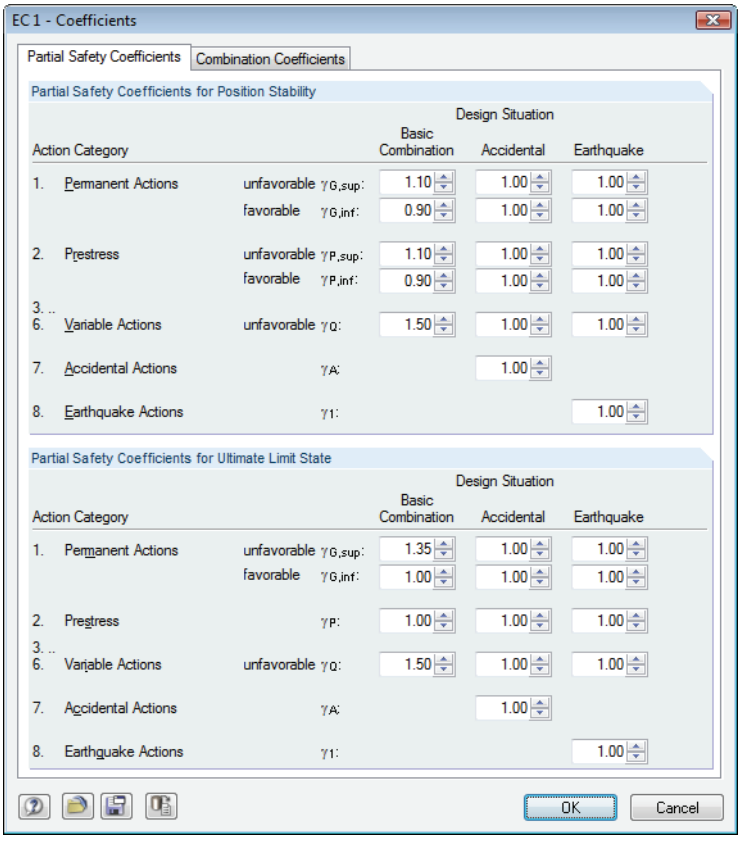

Figure 3.25: Dialog box *Coefficients*, default partial safety coefficients according to EN 1990 CZ

The *Combination Coefficients* differ according to the action categories.

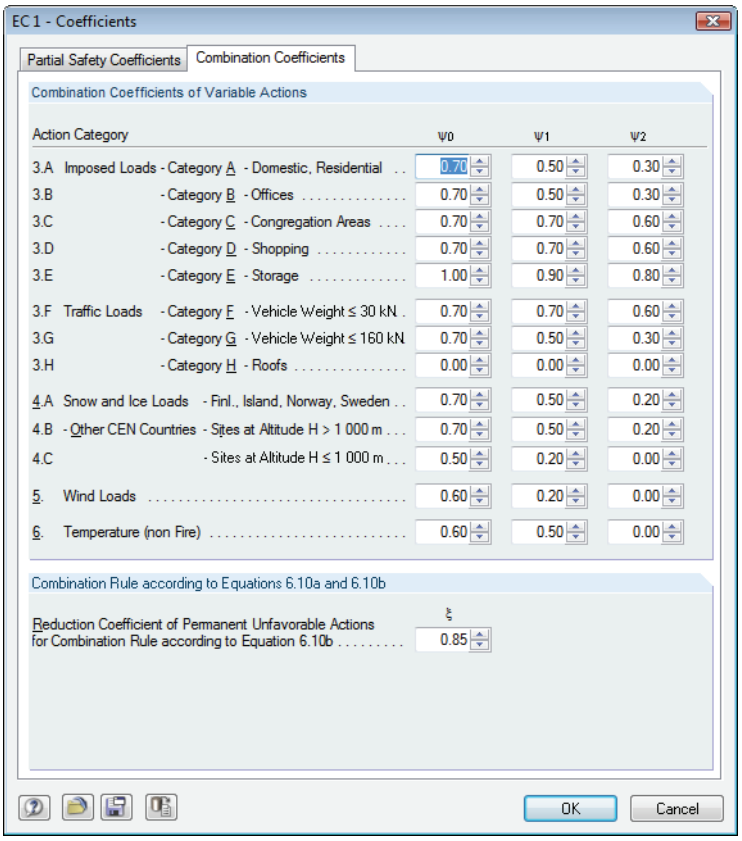

Figure 3.26: Dialog box *Coefficients*, default combination coefficients according to EN 1990 CZ

Apart from the coefficients that are set by default according to corresponding standards, you can also create and save your own sets of coefficients. This possibility is described in chapter 3.3.1.5 on page 19.

If the standard EN 1990 is applied, it is also necessary to enter the coefficient ξ, together with partial and combination coefficients. The coefficient ξ is used in formula 2.12 (it corresponds to formula 6.10b in EN 1990).

In the pictures, you can see default coefficients according to EN 1990 CZ. If you select the standard EN 1990 CEN, some coefficients will be different.

3.4 Results Masks

There are two results masks available in the RSCOMBI module. In the first mask, the generated results are listed by actions. This table corresponds to the definition of actions in a standard. In the second mask, the generated load groups or load combinations are listed individually, together with the included load cases.

3.4.1 Generation of Load Groups

3.4.1.1 Load Groups by Actions

The mask 2.1 *Load Groups by Actions* consists of two parts. In the upper table, the generated load groups by actions are shown in a general way. In the lower part, detailed information is given on the line which is selected in the upper table.

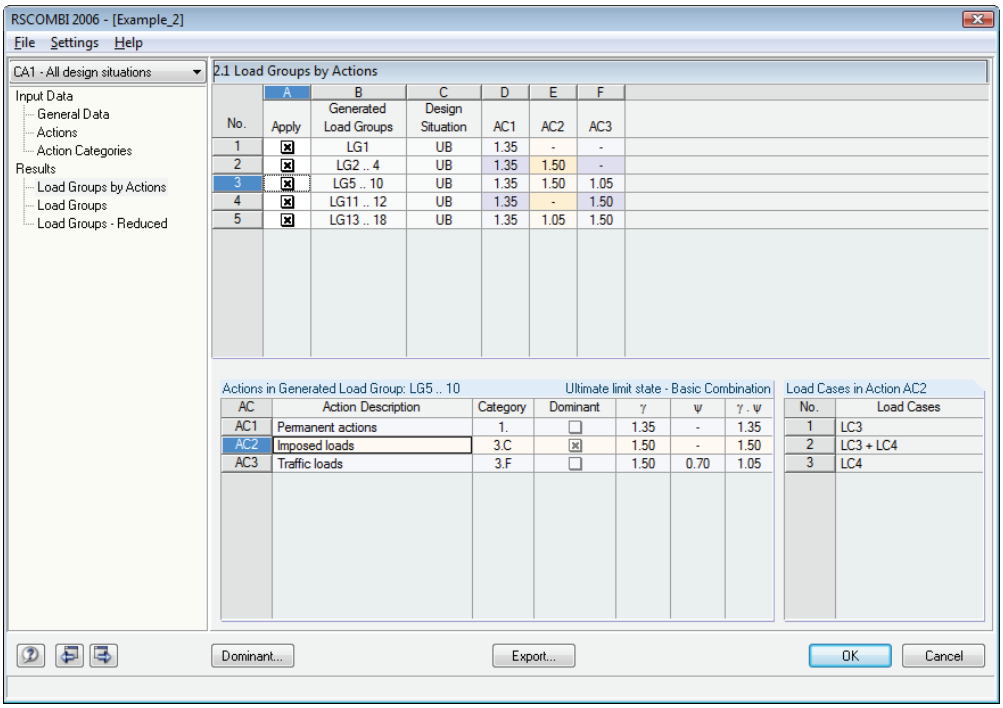

Figure 3.27: Mask 2.1 *Load Groups by Actions*

The upper table contains several columns. In the first column *No.*, the individual entries are listed by numbers. In the column *Apply*, you can activate check boxes and, thus, decide which load groups are to be exported to RSTAB.

In the column *Generated Load Groups*, you see which load groups belong to an entry. In the column *Design Situation*, you find a description of the design situation for which corresponding load groups were generated. The descriptions from mask 1.1 are applied here. In the remaining columns, the actions are displayed with the relevant coefficients.

If you click any item in the upper table, more data is shown in the lower table. In the section *Actions in Generated Load Groups*, the list of all considered actions is displayed, including their *Description* and *Action Categories* (see mask 1.3).

In the column *Dominant*, the main action is marked. The action is considered dominant if it acts as $Q_{k,1}$ in formulas 2.1, 2.2, 2.4, 2.5, 2.10, 2.11, 2.13 or 2.14 (see chapter 2.2). The applied coefficients γ, ψ and ξ of every action are determined according to the design situation and action category. The action coefficient in an entry represents the product of these factors.

If you click any action in the section *Actions in Generated Load Groups*, the corresponding load cases shown in the section *Load Cases in Action AC#*. Additionally, all possibilities how to consider these load cases in a given action can be read. These possibilities depend on the action category and on the possible 'Alternative' relation of the actions. It is assumed that in case of the action categories 'Permanent' or 'Prestress', all allocated load cases are considered simultaneously, unless an alternative relation was defined among them. In case of the action categories 'Variable', 'Accidental', and 'Seismic', the allocated load cases can be superimpose in all possible combinations.

In Figure 3.27, an example is shown in which 18 load groups in total were generated for the design situation 'Ultimate limit state – basic combination'. For all five entries, you can see how the relevant actions were applied in the formula of this design situation. The third entry is *1.35 AC1 + 1.50 AC2 + 1.05 AC3*. By considering these actions, six load groups are generated that are described as *LG5 .. 10*.

The first action AC1 is named *Permanent actions*. It was allocated to category 1 (*Permanent actions*) in mask 1.3 and is used with the coefficient $\gamma = 1.35$ in the generated load groups.

The second action AC2 is named *Imposed loads*. It was allocated to category 3.C (*Imposed loads, category C - congregation areas*) in mask 1.3 and is used with the coefficient $\gamma = 1.50$ in the generated load groups. It is the dominant load that can appear as *LC3* or *LC3 + LC4* or *LC4*.

The third action AC3 is named *Traffic loads*. It was allocated to category 3.F (*Traffic loads, category F - vehicle weight $<$ 30 kN*) in mask 1.3 and is multiplied with the coefficient $\gamma * \psi = 1.50 * 0.70 = 1.05$ in the generated load groups.

3.4.1.2 Load Groups

The mask 2.2 *Load Groups* consists of two parts, too. In the upper part, all generated load groups are listed. In the lower part, detailed information is is given on the line which is selected in the upper table.

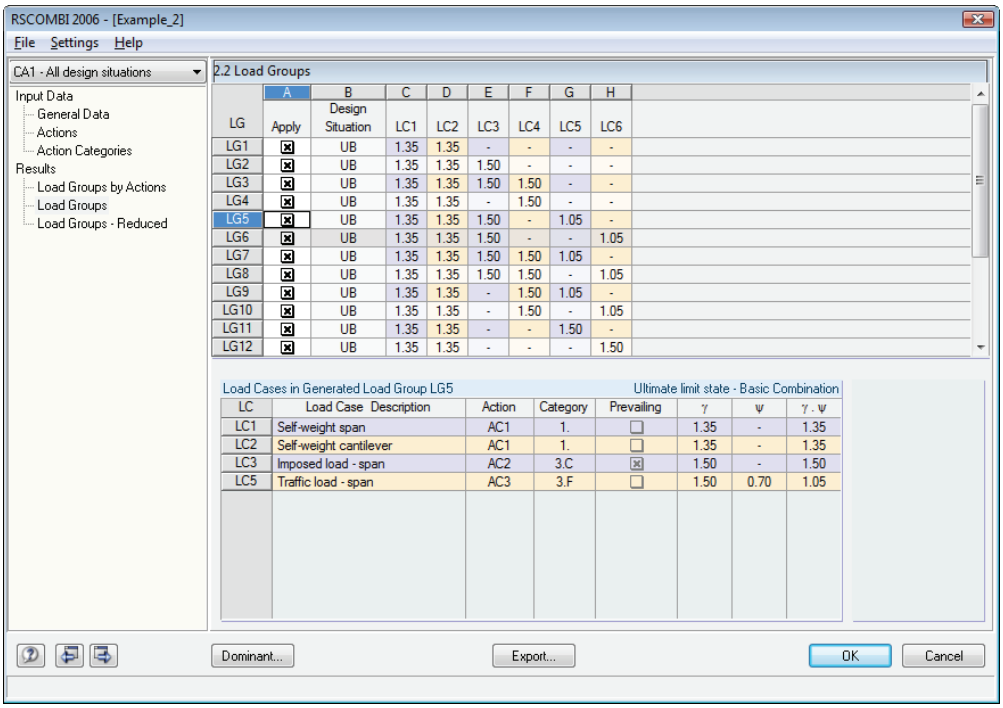

Figure 3.28: Mask 2.1 *Load Groups*

The upper table contains several columns. In the first column *LG*, the numbers of all generated load groups are displayed. In the column *Apply*, you can activate check boxes and, thus, decide which load groups are to be exported to RSTAB. This column is synchronized with the same column in mask 2.1. In the column *Design Situation*, you find a description of the design situation for which corresponding load groups were generated. In the remaining columns, the load cases are displayed that are contained in each load group.

If you click any item in the upper table, details of the selected load group are shown in the lower table. In the column *LC* in the lower table, all load cases are shown that are included in this load group. Their *Description* appears in the next column. In the column *Action*, the actions which have been allocated to each load case in mask 1.2 is displayed. In the column *Category*, the relevant action category is shown and in the column *Prevailing*, the main action in a given load group is marked. The coefficients γ, ψ, and ξ for every action, which are applied in the load group, are determined on the basis of the design situation and action category. The action coefficients represent the products of these factors.

In Figure 3.28, you can see the first 12 load groups from the total number of 18 generated load groups. LG5 consists of *1.35LC1 + 1.35LC2 + 1.5LC3 + 1.05LC5*. The load cases LC1 and LC2 belong to action AC1. Action AC1 was allocated to category 1 (*Permanent actions)* in mask 1.3. It is multiplied by the coefficient γ =1.35 in this load group LG5. Load case LC3 belongs to action AC2. Action AC2 was allocated to category 3.C (*Imposed loads, category C - congregation areas)*. It is the prevailing load case in LG5 and, therefore, is multiplied by the coefficient γ =1.50. Load case LC5 belongs to action AC3. Action AC3 was allocated to to category 3.F (*Traffic loads, category F - vehicle weight < 30 kN*) in mask 1.3. It is multiplied by the coefficient $\gamma^*\psi$ = 1.50*0.70 = 1.05 in LG5.

If you compare Figure 3.27 and Figure 3.28, you find out that the third entry of the generated load groups in Figure 3.27 (*1.35AC1+1.50AC2+1.05AC3*) corresponds to load groups LG5 .. 10.

The load groups LG5 to LG10 are described in Figure 3.28 as follows:

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

Action AC1 includes the load cases LC1 and LC2. Regarding the fact that it is a permanent action, both load cases can occur only simultaneously. Action AC2 includes the load cases LC3 and LC4. As it is a variable action, three combinations are possible: *LC3* or *LC3 + LC4* or *LC4.* Action AC3 includes the load cases LC5 and LC6. It is a variable action, too. Because an '*Alternative*' relation was defined between LC5 and LC6, the combinations *LC5 or LC6* originate. If the actions are replaced by load cases, the entry *1.35AC1 + 1.50AC2 + 1.05AC3* represents in total 1*3*2 = 6 load groups which are specified as **LG5 .. 10** in Figure 3.27.

In this way, you can retrace the load groups in mask 2.2 that are contained in every table row in mask 2.1. All possible combinations are created, unless you have ticked the option *Reduce possible load groups by examining RSTAB results* in mask 1.1. In this case, only the decisive load groups are generated. You can also retrace the load groups of mask 2.1 in mask 2.2, but be aware that many generated load groups have not been considered here.

3.4.2 Generation of Load Combinations

3.4.2.1 Load Combinations by Actions

The mask 2.1 *Load Combinations by Actions* consists of two parts. In the upper table, the generated load combinations by actions are shown in a general way. In the lower part, detailed information is given on the line which is selected in the upper table.

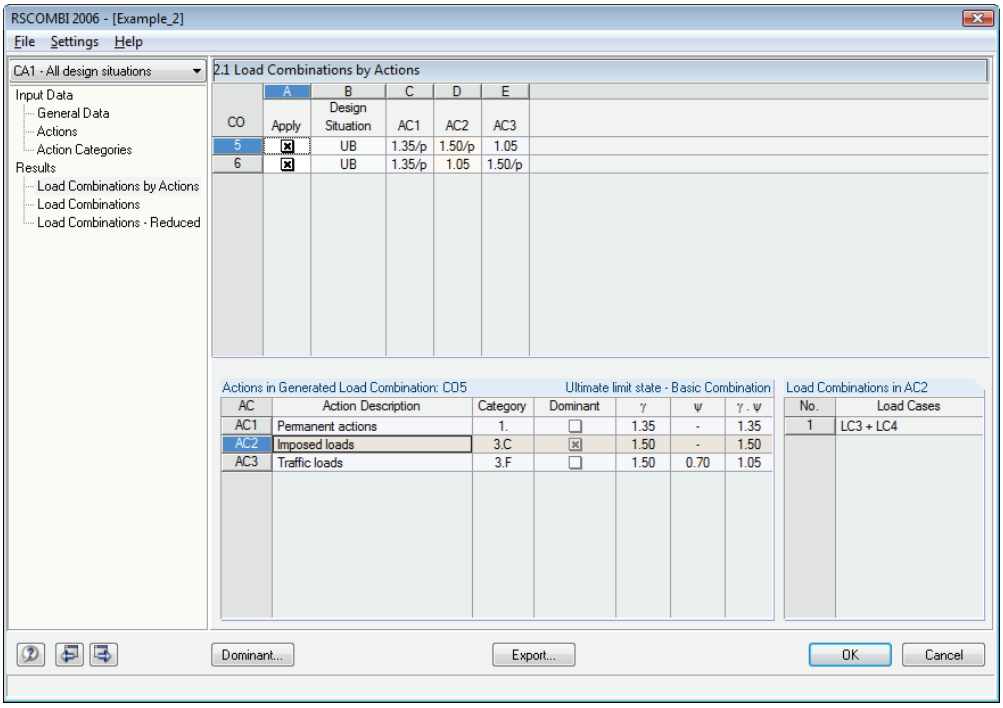

Figure 3.29: Mask 2.1 *Load Combinations by Actions*

The mask layout is similar to the mask described in chapter 3.4.1.1 on page 30. Hence, it is not described here again.

In Figure 3.29, you can see the results of the same example as in Figure 3.27. The difference is that loads with the combination criterion 'variable' enter combinations as possible ones, i.e. only if their internal forces increase the internal forces of the combined results.

In Figure 3.29, you can see that the two load combinations CO5 and CO6 were generated for the design situation 'Ultimate limit state - basic combination'. This means that four internal load combinations must have been created in individual actions. For example, see load combination CO5 *1.35AC1/p + 1.50AC2/p + 1.05AC3*. Actions with the symbol "/p" are considered as 'permanent' in a combination, actions without the symbol as 'variable'. The first action AC1 this combination was classified as *Permanent action*. It was allocated to category 1 (*Permanent actions*) in mask 1.3 and is multiplied by the coefficient $\gamma = 1.35$ in the generated load combination. The second action AC2 was described as *Imposed load* and allocated to category 3.C (*Imposed loads, category C - congregation areas*) in mask 1.3. It is multiplied by the coefficient $\gamma = 1.50$ in the generated load combination. It represents the prevailing load. Action AC2 includes the load cases LC3 and LC4. The respective internal combination CO2 is *LC3 + LC4* (see Figure 3.30) and includes all options how to combine the load cases LC3 and LC4 in action AC2. The third action AC3 represents a *Traffic load* and was allocated to category 3.F (*Traffic loads, category F - vehicle weight < 30 kN*) in mask 1.3. It is multiplied by the coefficient $\gamma*\psi = 1.50*0.70 = 1.05$ in the generated load combination.

3.4.2.2 Load Combinations

The mask 2.2 *Load Combinations* consists of two parts. In the upper part, all generated load combinations are listed. In the lower part, detailed information is shown about a load combination that is currently selected in the upper table.

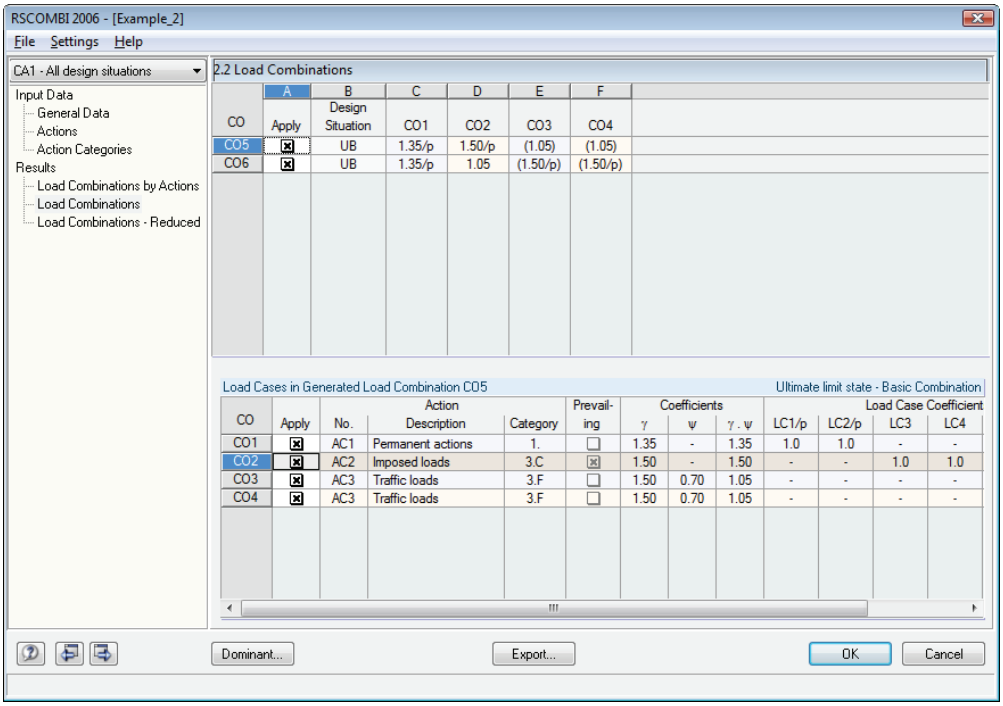

Figure 3.30: Mask 2.2 *Load Combinations*

The layout of this mask is similar to the mask described in chapter 3.4.1.2 on page 32. Hence, it is not described here again.

In Figure 3.30, you can see that two load combinations CO5 and CO6 were generated for the design situation 'Ultimate limit state - basic combination'. Combination CO5 is defined as *1.35CO1/p + 1.50CO2/p + 1.05CO3* or *1.05CO4*. The first internal load combination CO1 belongs to action AC1 which was described as "permanent" and allocated to category 1 (*Permanent actions*). Both AC1 and CO1 are multiplied by the coefficient $\gamma = 1.35$ in the load combination CO5. The load combination CO1 consists of LC1/p + LC2/p. The second internal load combination CO2 belongs to action AC2 which was described as *Imposed load* and was allocated to category 3.C (*Imposed loads, category C - congregation areas*). It represents the prevailing action. In the load combination CO5, both AC2 and CO2 are multiplied by the coefficient $\gamma = 1.35$. The load combination CO2 consists of *LC3 + LC4*. The third and fourth load combinations CO3 and CO4 belong to action AC3, type *Traffic load*. It was allocated to category 3.F (*Traffic loads, category F - vehicle weight < 30 kN*). Both AC3 and CO3 and CO4 are multiplied by the coefficient $\gamma * \psi = 1.5 * 0.70 = 1.05$ in load combination CO5. The load combination CO3 includes LC5, and the combination CO4 includes LC6.

3.5 Main Menus

The main menus contain all necessary commands for processing cases in RSCOMBI. You open the main menu by clicking its name or by pressing the [Alt] key together with the key whose letter is underlined in the menu name. For the main menu *File*, you press [Alt+F]. The commands contained in the main menus are also called up by pressing their underlined letter on the keyboard.

3.5.1 File

New Case

This command is used to create a new case of generation data.

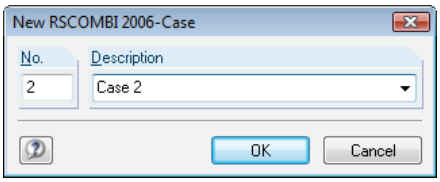

Figure 3.31: Dialog box *New RSCOMBI 2006-Case*

In the dialog box, it is necessary to enter the *No.* and *Description* of a new case. If you click the button [▼], the list of all already used cases is shown.

In the new case, you can save another independent set of input and output data.

Rename Case

This command changes the *Description* of the current case in RSCOMBI and optionally also assigns a different number to this case.

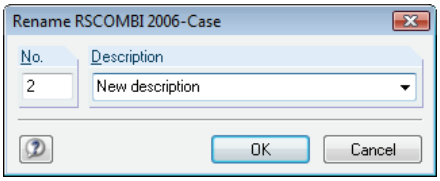

Figure 3.32: Dialog box *Rename RSCOMBI 2006-Case*

Copy Case

This command copies data of the current case to a new case. You can change the *No.* and enter the *Description* of the new case.

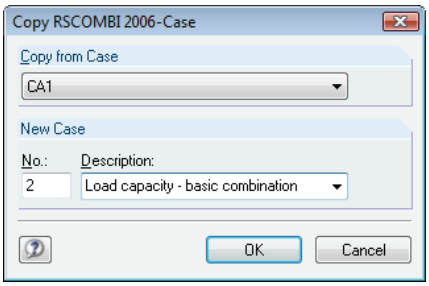

Figure 3.33: Dialog box *Copy RSCOMBI 2006-Case*

Delete Case

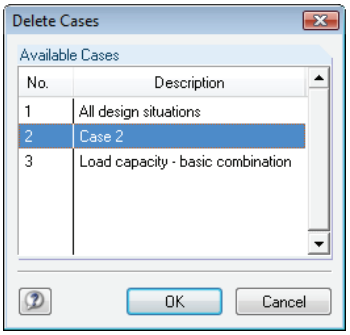

Figure 3.34: Dialog box *Delete Cases*

When you click this command, the list of all cases created in RSCOMBI is shown. Click the case you wish to delete. After closing the dialog box by the [OK] button, the selected case is deleted. If you want to select more cases by the mouse, you must hold down the [Ctrl] key.

3.5.2 Settings

Reduction by Selecting Dominant Actions

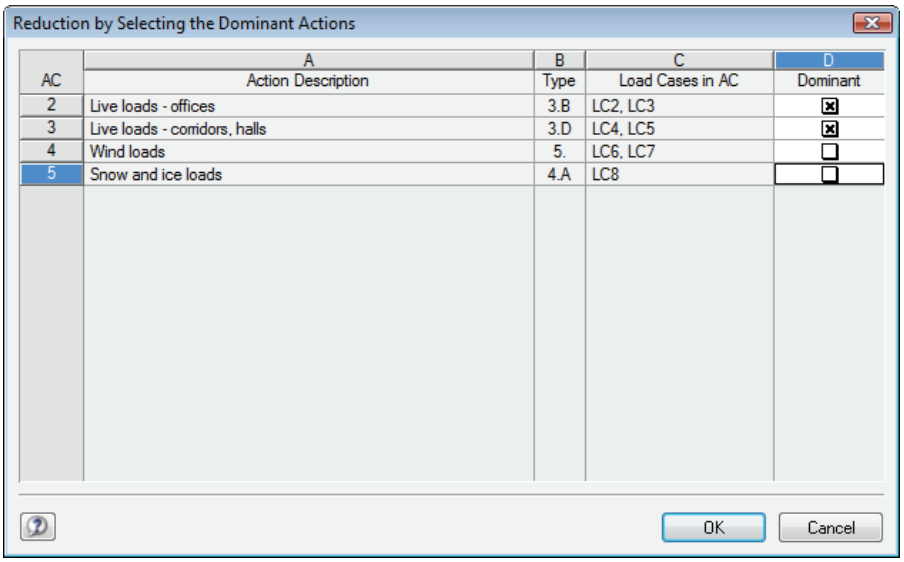

Figure 3.35: Dialog box *Reduction by Selecting Dominant Actions*

It is possible to previously select the dominant actions by using the check box in column D *Dominant*. Thus, the number of generated load groups or combinations can be reduced considerably.

3.5.3 Help

This main menu calls up the *Help* function that is derived from this manual, but it may be more up-to-date than the printed version.

4. Printing

If you want to print the input and output data of RSCOMBI, you have to return to the main program RSTAB. Then call up the command [Current Printout Report].

The functions how to edit and change the layout of the printout report are described chapter 10.1 of the RSTAB manual.

In the dialog box *Printout Report Selection*, more tabs become available when you click the item **RSCOMBI 2006** in the list *Program* / *Modules* on the left.

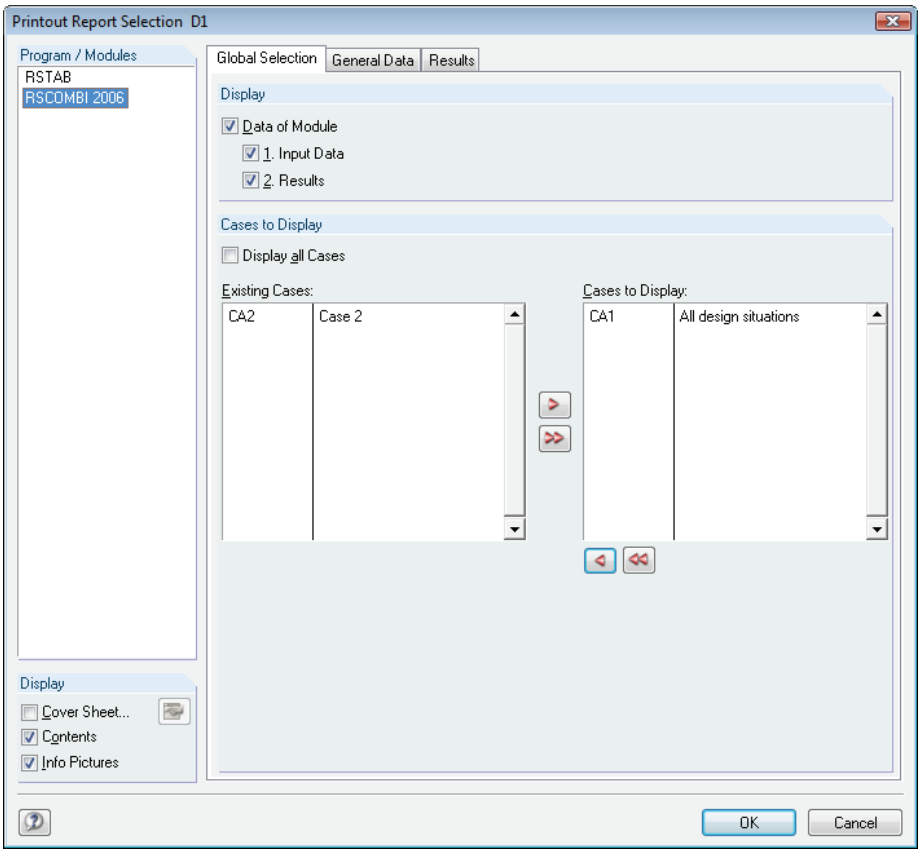

Figure 4.1: Dialog box *Printout Report Selection*: RSCOMBI 2006 and its tabs with detailed data

5. Examples

5.1 Single-Span Girder (DIN 1055-100)

Structure and loads

A single-span girder is loaded by five load cases. Every load case represents an individual action. The load cases and girder have already been defined in RSTAB.

Load case	Action	Action category
LC1	AC1	permanent
LC2	AC2	imposed loads, 3.C - congregation areas $\psi_0 = 0.70$, $\psi_1 = 0.70$, $\psi_2 = 0.60$
LC3	AC3	traffic loads, 3.F – vehicle weight < 30 kN $\psi_0 = 0.70$, $\psi_1 = 0.70$, $\psi_2 = 0.60$
LC4	AC4	accidental
LC5	AC5	seismic

Table 5.1: Load cases and actions

In RSCOMBI, load groups are to be generated for the design situation 'Ultimate limit state - basic combination' according to DIN 1055-100, and consequently also for all other design situations. These are then to be exported to RSTAB.

Input data

In the mask 1.1 *General Data*, you choose that **load groups** are to be generated according to **DIN 1055-100** for the design situation **Ultimate limit state – basic combination**.

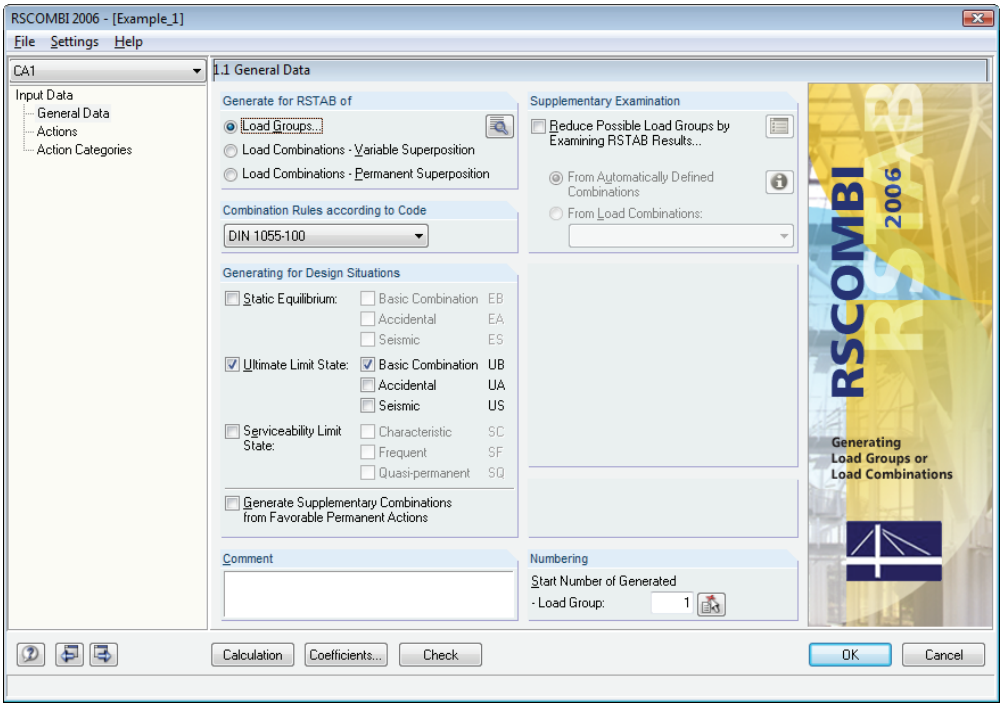

Figure 5.1: Mask 1.1 *General Data*

When you open mask 1.2, action **AC1** is created automatically and load case **LC1** is allocated to it. Other load cases defined in RSTAB are displayed in the list *Existing Load Cases*.

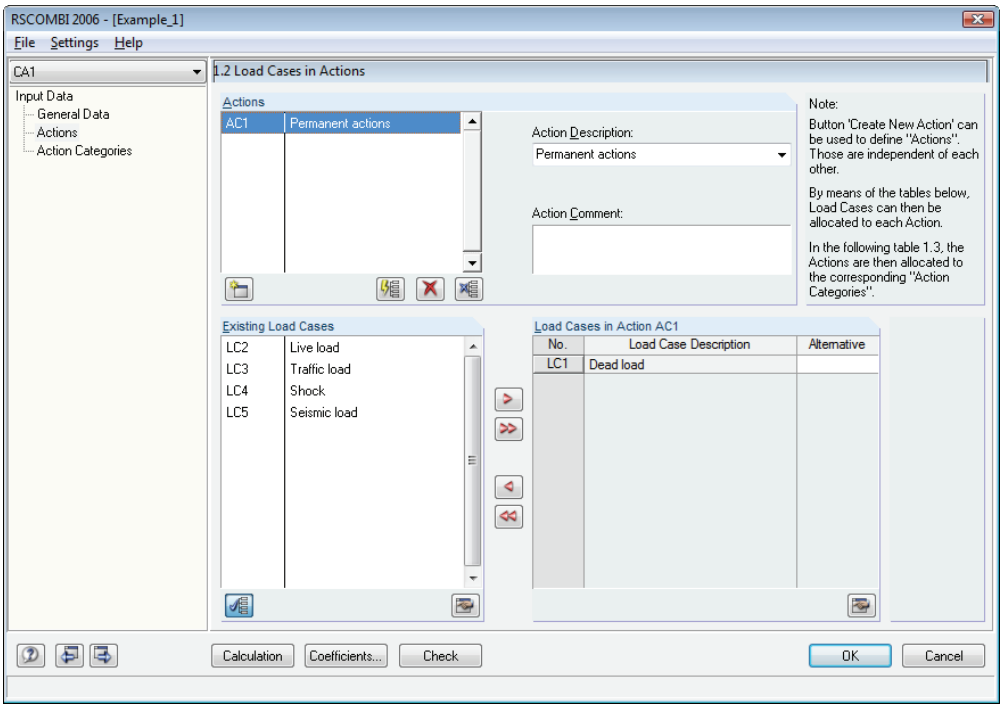

Figure 5.2: Mask 1.2 *Actions*

Regarding the fact that every load case represents one action, you can quickly create corresponding actions by using the second button in the section *Actions*. See this button here on the left. The individual load cases are then automatically allocated to actions. You can also add action descriptions.

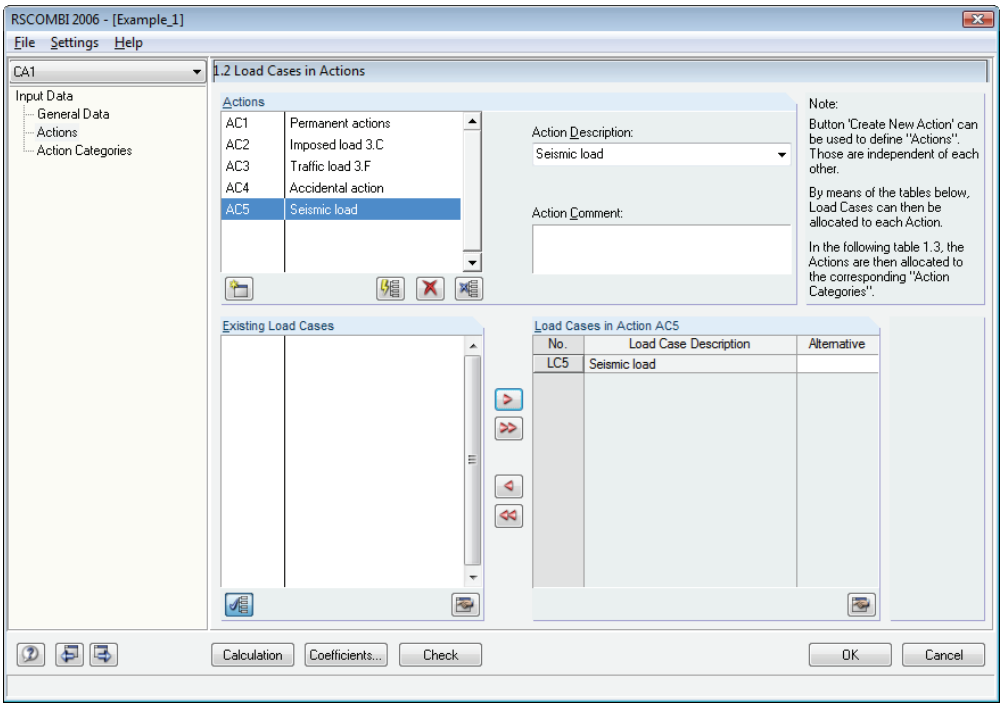

Figure 5.3: Actions with allocated load cases

The actions are then allocated to specific categories in mask 1.3 *Action Categories.*

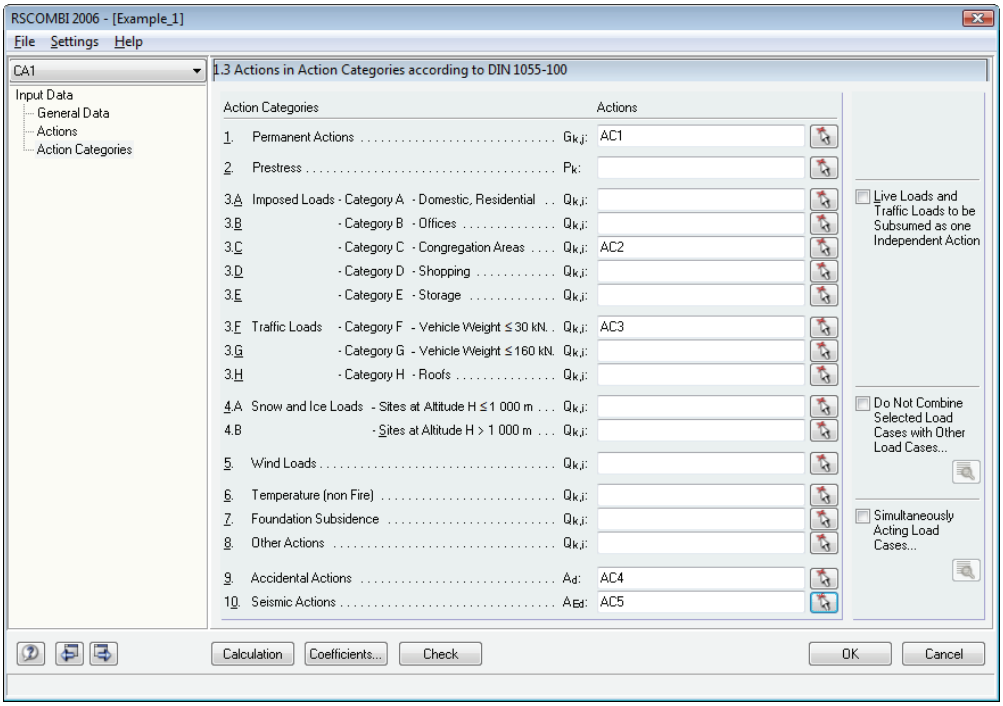

Figure 5.4: Mask 3.1 *Action Categories*

No imperfection-type load cases were defined in RSTAB for this example. Thus, the input is complete.

Results for design situation 'ULS - basic combination'

For the design situation 'Ultimate limit state - basic combination', five load groups are created according to formula 2.1 (see page 6).

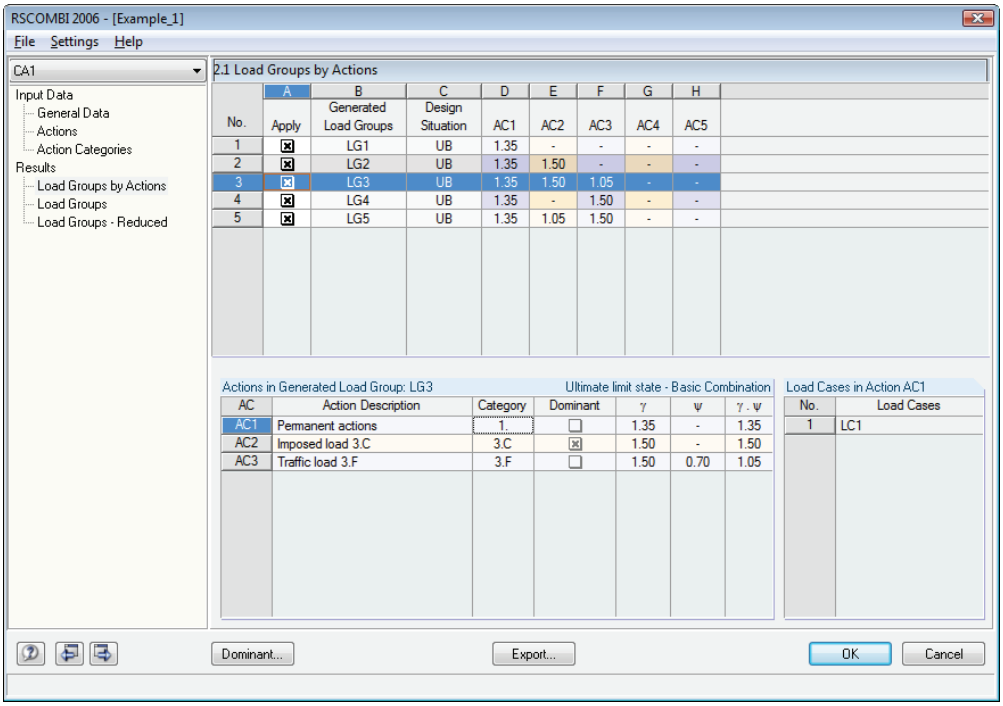

Figure 5.5: Mask 2.1 *Load Groups by Actions*

In mask 2.2, you can find the detailed results. These are sorted by *load cases* instead of *actions*.

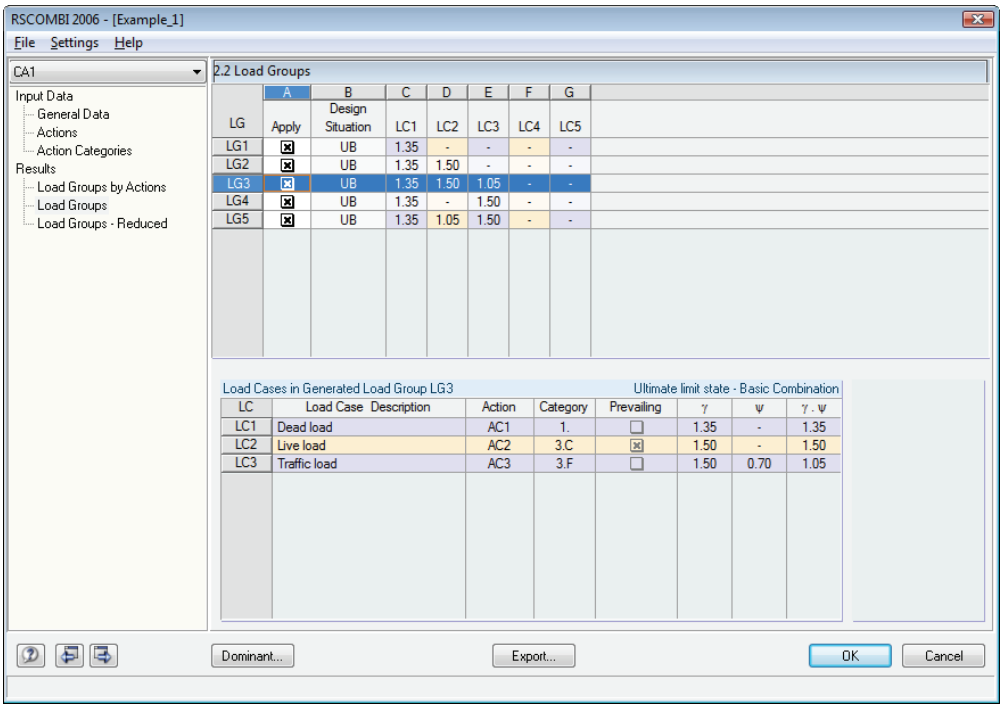

Figure 5.6: Mask 2.2 *Load Groups*

Results for all design situations

If you select all design situations in mask 1.1 (see Figure 5.1), the following load groups will be created:

- **10** load groups for the situation 'Static equilibrium - basic combination' (EB, LG1 .. 10, see formula 2.1)
- **10** load groups for the situation 'Static equilibrium - accidental' (EA, LG11 .. 20, see formula 2.2)
- **4** load groups for the situation 'Static equilibrium - seismic' (ES, LG21 .. 24, see formula 2.3)
- **5** load groups for the situation 'Ultimate limit state - basic combination' (UB, LG25 .. 29, see formula 2.1)
- **5** load groups for the situation 'Ultimate limit state - accidental' (UA, LG30 .. 34, see formula 2.2)
- **4** load groups for the situation 'Ultimate limit state - seismic' (US, LG35 .. 38, see formula 2.3)
- **5** load groups for the situation 'Serviceability limit state - characteristic' (SC, LG39 .. 43, see formula 2.4)
- **5** load groups for the situation 'Serviceability limit state - frequent' (SF, LG44 .. 48, see formula 2.5)
- **4** load groups for the situation 'Serviceability limit state - quasi-permanent' (SQ, LG49 .. 52, see formula 2.6)

2.2 Load Groups

LG	A Apply	B Design Situation	C LC1	D LC2	E LC3	F LC4	G LC5
LG1	☒	EB	1.10	-	-	-	-
LG2	☒	EB	1.10	1.50	-	-	-
LG3	☒	EB	1.10	1.50	1.05	-	-
LG4	☒	EB	1.10	-	1.50	-	-
LG5	☒	EB	1.10	1.05	1.50	-	-
LG6	☒	EB	0.90	-	-	-	-
LG7	☒	EB	0.90	1.50	-	-	-
LG8	☒	EB	0.90	1.50	1.05	-	-
LG9	☒	EB	0.90	-	1.50	-	-
LG10	☒	EB	0.90	1.05	1.50	-	-
LG11	☒	EA	1.00	-	-	1.00	-
LG12	☒	EA	1.00	0.70	-	1.00	-
LG13	☒	EA	1.00	0.70	0.60	1.00	-
LG14	☒	EA	1.00	-	0.70	1.00	-
LG15	☒	EA	1.00	0.60	0.70	1.00	-
LG16	☒	EA	0.95	-	-	1.00	-
LG17	☒	EA	0.95	0.70	-	1.00	-
LG18	☒	EA	0.95	0.70	0.60	1.00	-
LG19	☒	EA	0.95	-	0.70	1.00	-
LG20	☒	EA	0.95	0.60	0.70	1.00	-
LG21	☒	ES	1.00	-	-	-	1.00
LG22	☒	ES	1.00	0.60	-	-	1.00
LG23	☒	ES	1.00	0.60	0.60	-	1.00
LG24	☒	ES	1.00	-	0.60	-	1.00
LG25	☒	UB	1.35	-	-	-	-
LG26	☒	UB	1.35	1.50	-	-	-
LG27	☒	UB	1.35	1.50	1.05	-	-
LG28	☒	UB	1.35	-	1.50	-	-
LG29	☒	UB	1.35	1.05	1.50	-	-
LG30	☐	UA	1.00	-	-	1.00	-
LG31	☐	UA	1.00	0.70	-	1.00	-
LG32	☐	UA	1.00	0.70	0.60	1.00	-
LG33	☐	UA	1.00	-	0.70	1.00	-
LG34	☐	UA	1.00	0.60	0.70	1.00	-
LG35	☐	US	1.00	-	-	-	1.00
LG36	☐	US	1.00	0.60	-	-	1.00
LG37	☐	US	1.00	0.60	0.60	-	1.00
LG38	☐	US	1.00	-	0.60	-	1.00
LG39	☒	SC	1.00	-	-	-	-
LG40	☒	SC	1.00	1.00	-	-	-
LG41	☒	SC	1.00	1.00	0.70	-	-
LG42	☒	SC	1.00	-	1.00	-	-
LG43	☒	SC	1.00	0.70	1.00	-	-
LG44	☐	SF	1.00	-	-	-	-
LG45	☒	SF	1.00	0.70	-	-	-
LG46	☒	SF	1.00	0.70	0.60	-	-
LG47	☒	SF	1.00	-	0.70	-	-
LG48	☒	SF	1.00	0.60	0.70	-	-
LG49	☐	SQ	1.00	-	-	-	-
LG50	☒	SQ	1.00	0.60	-	-	-
LG51	☒	SQ	1.00	0.60	0.60	-	-
LG52	☒	SQ	1.00	-	0.60	-	-

Figure 5.7: Mask 2.2 *Load Groups*, all design situations (overall view)

When you export the 52 generated load groups to RSTAB, there is a possibility to export three 'Either-or' combinations additionally. For this, simply select this option in the section *Either/or Load Combination* in the *Export* dialog box (see Figure 5.8).

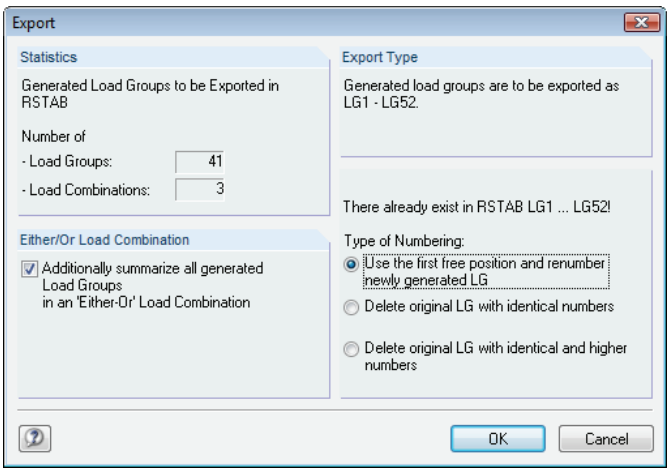

Figure 5.8: Dialog box *Export*

Three load combinations are created:

- CO1: LG1/p or LG2/p or LG3/p or ... or LG24/p
- CO2: LG25/p or LG26/p or LG27/p or LG28/p or LG29/p
- CO3: LG39/p or LG40/p or LG41/p or ... or LG52/p

CO1 determines the extreme values for the design situation 'Static equilibrium', CO2 the extreme values for the design situation 'Ultimate limit state', and CO3 the extreme values for the design situation 'Serviceability limit state'.

5.2 Girder with Cantilever (DIN 1055-100)

Structure and loads

A single-span girder with a cantilever beam is, similar to the previous example, loaded by permanent loads, live loads and traffic loads. The imposed loads are divided into two load cases: one part acts on the span, the other part on the cantilever.

Load case	Action	Action category
LC1, LC2	AC1	permanent
LC3, LC4	AC2	imposed 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 5.2: Load cases and actions

Load groups are to be generated for the design situation 'Ultimate limit state - basic combination' according to DIN 1055-100.

Input data

In the mask 1.1 *General Data*, you choose that **load groups** are to be generated according to **DIN 1055-100** for the design situation **Ultimate limit state - basic combination**.

To distinguish favorable and unfavorable actions of permanent loads, you select the option *Generate supplementary combinations from favorable permanent actions*.

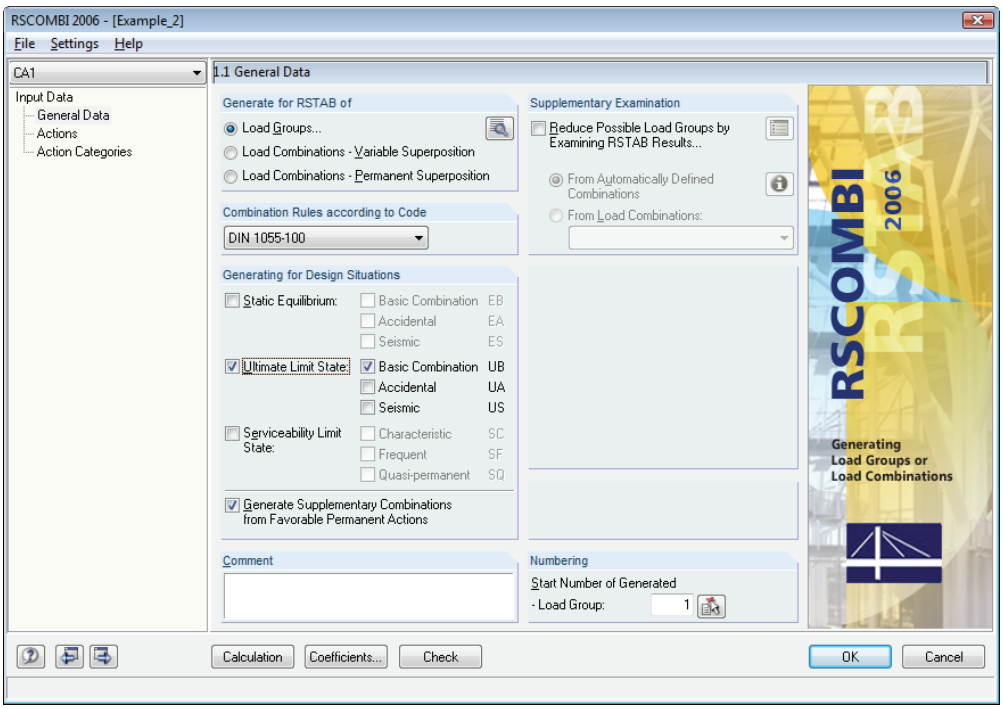

Figure 5.9: Mask 1.1 *General Data*

When you open mask 1.2, the action **AC1** is created automatically and load case **LC1** is allocated to it. This mask looks like the one of example 1 in Figure 5.2. However, it is necessary to allocate LC2 to AC1 as well, which you do by using the button displayed here on the left.

AC2 and AC3 are created by clicking the button [Create New Action] in the section *Actions*.

When allocating LC5 and LC6 to AC3, you must pay attention to their mutual exclusivity. Hence, you enter the same description in the *Alternative* column.

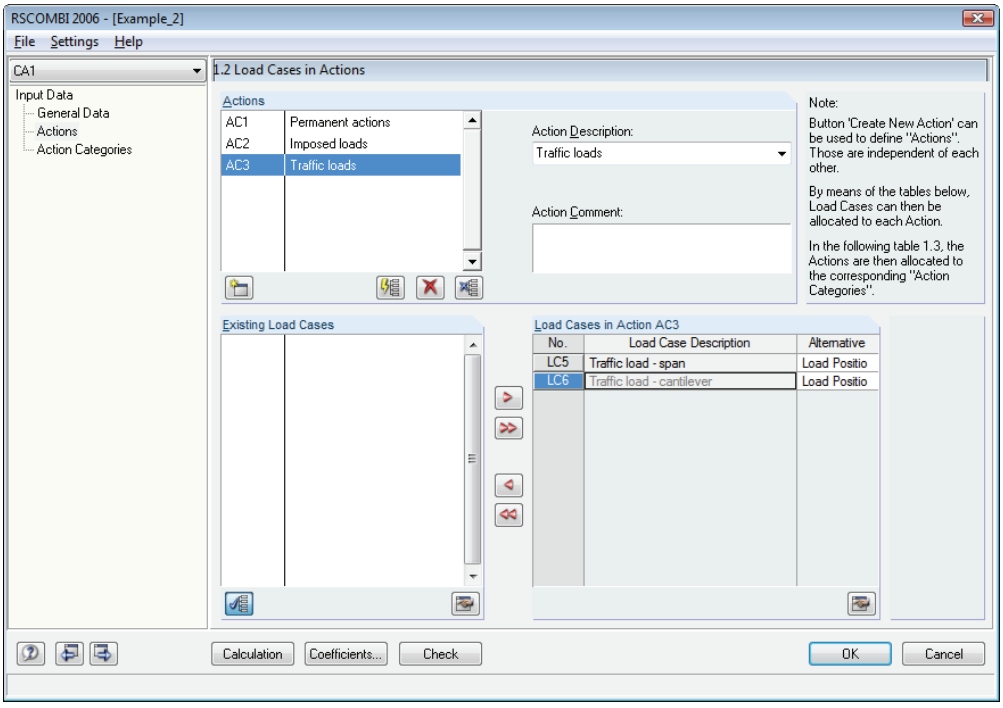

Figure 5.10: Mask 1.2 *Actions*

You carry out the allocation of actions AC1, AC2, and AC3 to corresponding categories like in example 1. There have no imperfections been defined in the second example, too.

Results

For the design situation 'Ultimate limit state - basic combination', 36 load groups are generated according to formula 2.1 (see page 6). These load groups are listed as 10 items in mask 2.1.

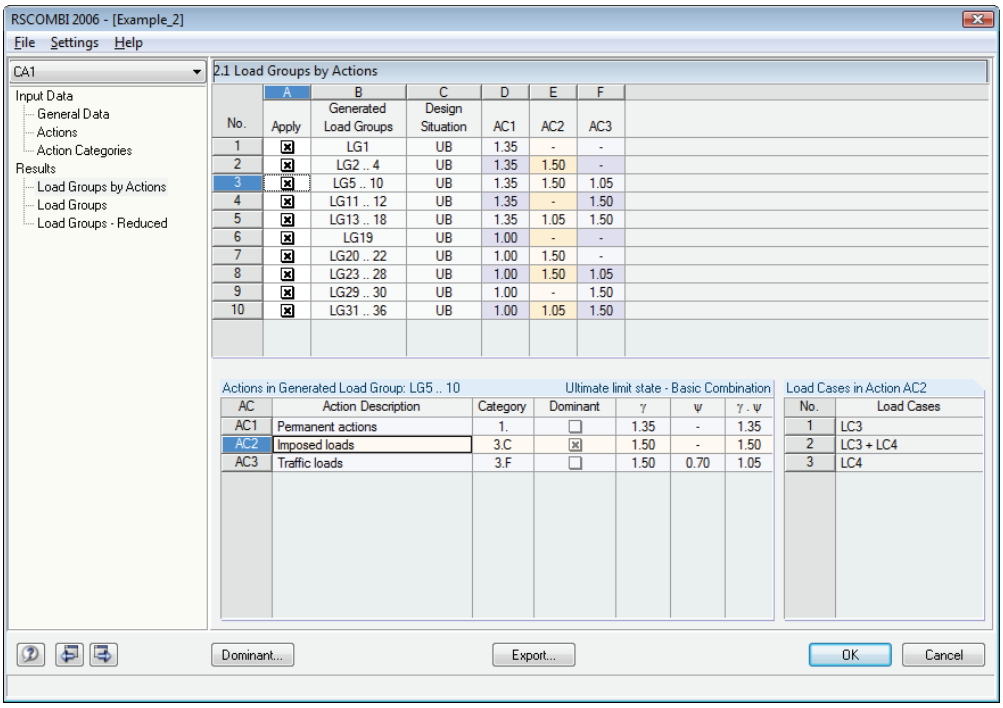

Figure 5.11: Mask 2.1 *Load Cases by Actions*

All generated load groups are individually shown in mask 2.2 *Load Groups*.

2.2 Load Groups

LG	A Apply	B Design Situation	C LC1	D LC2	E LC3	F LC4	G LC5	H 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
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
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 5.12: Mask 2.2 *Load Groups* (overall view)

When you compare masks 2.1 (Figure 5.11) and 2.2 (Figure 5.12), you can see that a total of six load groups in mask 2.2 correspond to the third table row in mask 2.1: *1.35AC1 + 1.50 AC2 + 1.05 AC3*:

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

These load groups can be retraced by substituting all possible load combinations by actions successively:

- AC1: LC1 + LC2
- AC2: LC3
LC3 + LC4
LC4
- AC3: LC5
LC6

Note

The permanent loads LC1 of the span and LC2 of the cantilever were allocated to the action AC1. Therefore, the same partial coefficients (1.35 or 1.00) are always assigned to both load cases in the load groups. If LC1 and LC2 act independently, you must allocate these load cases to different actions:

Load case	Action	Action category
LC1	AC1	permanent
LC2	AC2	permanent
LC3, LC4	AC3	imposed 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 5.3: LC1 and LC2 in different actions

In this case, the load cases LC1 and LC2 are multiplied by different partial coefficients. Then a total of 72 load groups will be generated.

2.1 Load Groups by Actions

No.	A Apply	B Generated Load Groups	C Design Situation	D AC1	E AC2	F AC3	G AC4
1	☒	LG1	UB	1.35	1.35	-	-
2	☒	LG2 .. 4	UB	1.35	1.35	1.50	-
3	☒	LG5 .. 10	UB	1.35	1.35	1.50	1.05
4	☒	LG11 .. 12	UB	1.35	1.35	-	1.50
5	☒	LG13 .. 18	UB	1.35	1.35	1.05	1.50
6	☒	LG19	UB	1.00	1.35	-	-
7	☒	LG20 .. 22	UB	1.00	1.35	1.50	-
8	☒	LG23 .. 28	UB	1.00	1.35	1.50	1.05
9	☒	LG29 .. 30	UB	1.00	1.35	-	1.50
10	☒	LG31 .. 36	UB	1.00	1.35	1.05	1.50
11	☒	LG37	UB	1.00	1.00	-	-
12	☒	LG38 .. 40	UB	1.00	1.00	1.50	-
13	☒	LG41 .. 46	UB	1.00	1.00	1.50	1.05
14	☒	LG47 .. 48	UB	1.00	1.00	-	1.50
15	☒	LG49 .. 54	UB	1.00	1.00	1.05	1.50
16	☒	LG55	UB	1.35	1.00	-	-
17	☒	LG56 .. 58	UB	1.35	1.00	1.50	-
18	☒	LG59 .. 64	UB	1.35	1.00	1.50	1.05
19	☒	LG65 .. 66	UB	1.35	1.00	-	1.50
20	☒	LG67 .. 72	UB	1.35	1.00	1.05	1.50

Figure 5.13: Mask 2.1 *Load Groups by Actions* (LC1 and LC2 in different actions)

5.3 Skeleton Structure (DIN 1055-100)

Structure and loads

A skeleton structure is loaded by permanent load, live load of office areas, live load of shopping areas, wind and snow.

Load case	Action	Action category
LC1	AC1	permanent
LC2, LC3	AC2	imposed loads, 3.B - offices $\psi_0 = 0.70$, $\psi_1 = 0.50$, $\psi_2 = 0.30$
LC4, LC5	AC3	imposed loads, 3.D - shopping $\psi_0 = 0.70$, $\psi_1 = 0.70$, $\psi_2 = 0.60$
LC6 or LC7	AC4	5. - wind loads $\psi_0 = 0.60$, $\psi_1 = 0.50$, $\psi_2 = 0$
LC8	AC5	4.A - snow and ice loads - sites at altitude < 1000 m $\psi_0 = 0.50$, $\psi_1 = 0.20$, $\psi_2 = 0$

Table 5.4: Load cases and actions

There are load groups and load combinations to be generated for the design situation 'Ultimate limit state - basic combination' according to DIN 1055-100.

Input data for generation of load groups

In mask 1.1 *General Data*, you choose that **load groups** are to be generated according to **DIN 1055-100** for the design situation **Ultimate limit state - basic combination**.

When you open mask 1.2, the action **AC1** is created automatically and load case **LC1** is allocated to it. This mask looks like the one of example 1 in Figure 5.2.

The actions AC2 to AC5 are created by using the button [Create New Action] in the section *Actions*. When allocating LC6 and LC7 to AC4, you must pay attention to their mutual exclusivity. Hence, you enter the same description in the *Alternative* column.

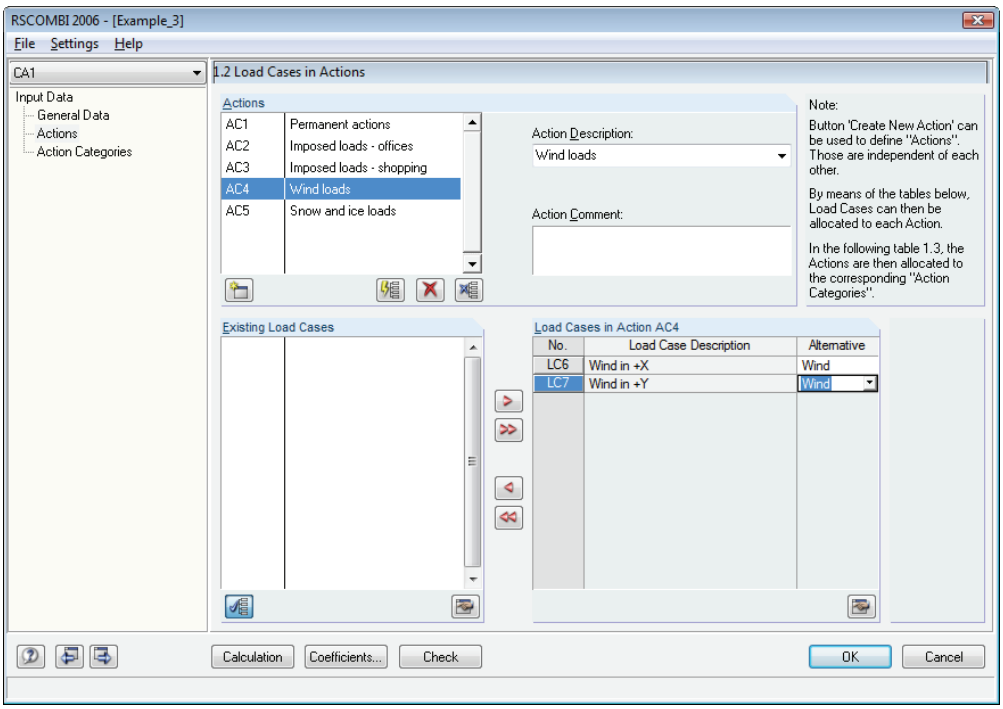

Figure 5.14: Mask 1.2 *Actions*

The actions are then allocated to specific categories in mask 1.3. For the two live loads, it is necessary to create two actions AC2 and AC3 because different combination coefficients ψ apply for offices (LC2 and LC3, AC2) and for shopping areas (LC4 and LC5, AC3). However, according to [9], annex A, page 37, imposed and traffic loads within one building are usually can be joined to one independent action. All imposed and traffic loads are considered as one action in the combination according to formula 2.1 (see page 6) for the design situation 'Ultimate limit state - basic combination' if you activate the option *Live loads and traffic loads to be subsumed as one independent action*.

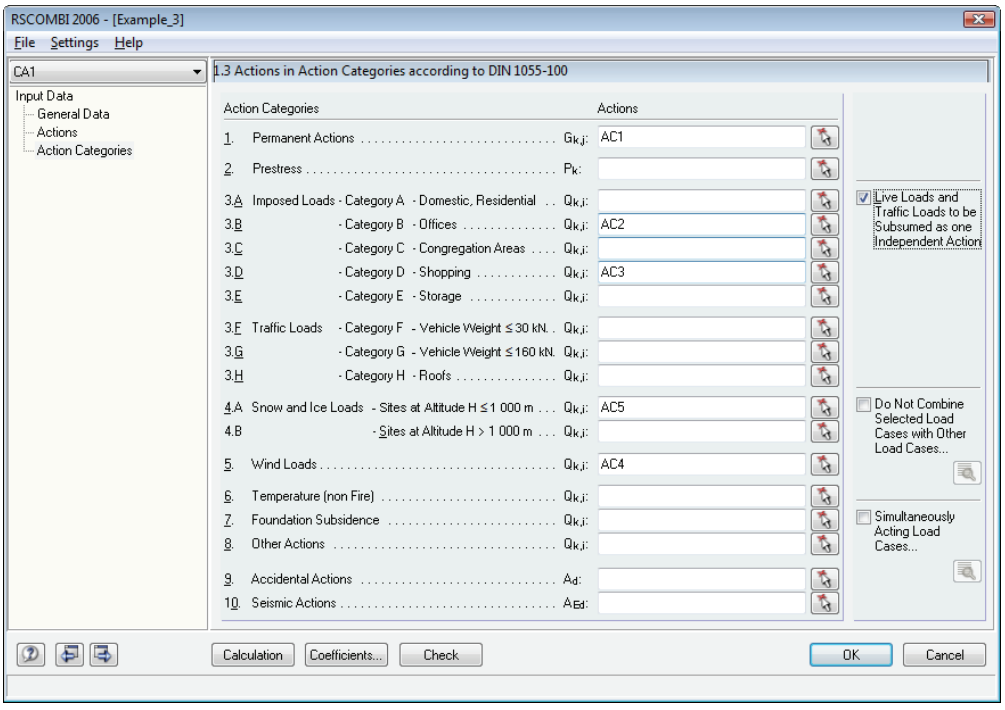

Figure 5.15: Mask 1.3 *Action Categories*

There have no imperfections been defined in this example.

Results

203 load groups are generated for the design situation 'Ultimate limit state - basic combination' according to formula 2.1 (see page 6). In mask 2.1, these are shown as follows:

2.1 Load Groups by Actions

No.	A Apply	B Generated Load Groups	C Design Situation	D AC1	E AC2	F AC3	G AC4	H AC5
1	☒	LG1	UB	1.35	-	-	-	-
2	☒	LG2 .. 4	UB	1.35	1.50	-	-	-
3	☒	LG5 .. 13	UB	1.35	1.50	1.50	-	-
4	☒	LG14 .. 31	UB	1.35	1.50	1.50	0.90	-
5	☒	LG32 .. 49	UB	1.35	1.50	1.50	0.90	0.75
6	☒	LG50 .. 58	UB	1.35	1.50	1.50	-	0.75
7	☒	LG59 .. 64	UB	1.35	1.50	-	0.90	-
8	☒	LG65 .. 70	UB	1.35	1.50	-	0.90	0.75
9	☒	LG71 .. 73	UB	1.35	1.50	-	-	0.75
10	☒	LG74 .. 76	UB	1.35	-	1.50	-	-
11	☒	LG77 .. 82	UB	1.35	-	1.50	0.90	-
12	☒	LG83 .. 88	UB	1.35	-	1.50	0.90	0.75
13	☒	LG89 .. 91	UB	1.35	-	1.50	-	0.75
14	☒	LG92 .. 93	UB	1.35	-	-	1.50	-
15	☒	LG94 .. 99	UB	1.35	1.05	-	1.50	-
16	☒	LG100 .. 117	UB	1.35	1.05	1.05	1.50	-
17	☒	LG118 .. 135	UB	1.35	1.05	1.05	1.50	0.75
18	☒	LG136 .. 141	UB	1.35	1.05	-	1.50	0.75
19	☒	LG142 .. 147	UB	1.35	-	1.05	1.50	-
20	☒	LG148 .. 153	UB	1.35	-	1.05	1.50	0.75
21	☒	LG154 .. 155	UB	1.35	-	-	1.50	0.75
22	☒	LG156	UB	1.35	-	-	-	1.50
23	☒	LG157 .. 159	UB	1.35	1.05	-	-	1.50
24	☒	LG160 .. 168	UB	1.35	1.05	1.05	-	1.50
25	☒	LG169 .. 186	UB	1.35	1.05	1.05	0.90	1.50
26	☒	LG187 .. 192	UB	1.35	1.05	-	0.90	1.50
27	☒	LG193 .. 195	UB	1.35	-	1.05	-	1.50
28	☒	LG196 .. 201	UB	1.35	-	1.05	0.90	1.50
29	☒	LG202 .. 203	UB	1.35	-	-	0.90	1.50

Figure 5.16: Mask 2.1 *Load Groups by Actions* (overall view)

The fact that actions AC2 and AC3 are considered as one action can be seen in the results: These two actions are taken into account together either as dominant load $Q_{k,1}$ (coefficient 1.5) or as secondary load $Q_{k,i}$ (coefficient 1.05).

Thus, both AC2 and AC3 are considered as *Dominant* actions in load groups LG14 to LG31.

2.1 Load Groups by Actions

No.	A Apply	B Generated Load Groups	C Design Situation	D AC1	E AC2	F AC3	G AC4	H AC5
1	☒	LG1	UB	1.35	-	-	-	-
2	☒	LG2 .. 4	UB	1.35	1.50	-	-	-
3	☒	LG5 .. 13	UB	1.35	1.50	1.50	-	-
4	☒	LG14 .. 31	UB	1.35	1.50	1.50	0.90	-
5	☒	LG32 .. 49	UB	1.35	1.50	1.50	0.90	0.75
6	☒	LG50 .. 58	UB	1.35	1.50	1.50	-	0.75
7	☒	LG59 .. 64	UB	1.35	1.50	-	0.90	-
8	☒	LG65 .. 70	UB	1.35	1.50	-	0.90	0.75
9	☒	LG71 .. 73	UB	1.35	1.50	-	-	0.75
10	☒	LG74 .. 76	UB	1.35	-	1.50	-	-
11	☒	LG77 .. 82	UB	1.35	-	1.50	0.90	-
12	☒	LG83 .. 88	UB	1.35	-	1.50	0.90	0.75

Actions in Generated Load Group: LG14 .. 31 — Ultimate limit state - Basic Combination

AC	Action Description	Category	Dominant	γ	ψ	γ . ψ
AC1	Permanent actions	1.	☐	1.35	-	1.35
AC2	Imposed loads - offices	3.B	☒	1.50	-	1.50
AC3	Imposed loads - shopping	3.D	☒	1.50	-	1.50
AC4	Wind loads	5.	☐	1.50	0.60	0.90

Figure 5.17: Actions in generated load groups LG14 .. 31

Input data for generation of load combinations

The input data differs from the previous entry in one thing only: in mask 1.1, you select the option **Load combinations - variable superposition** in section *Generate for RSTAB*.

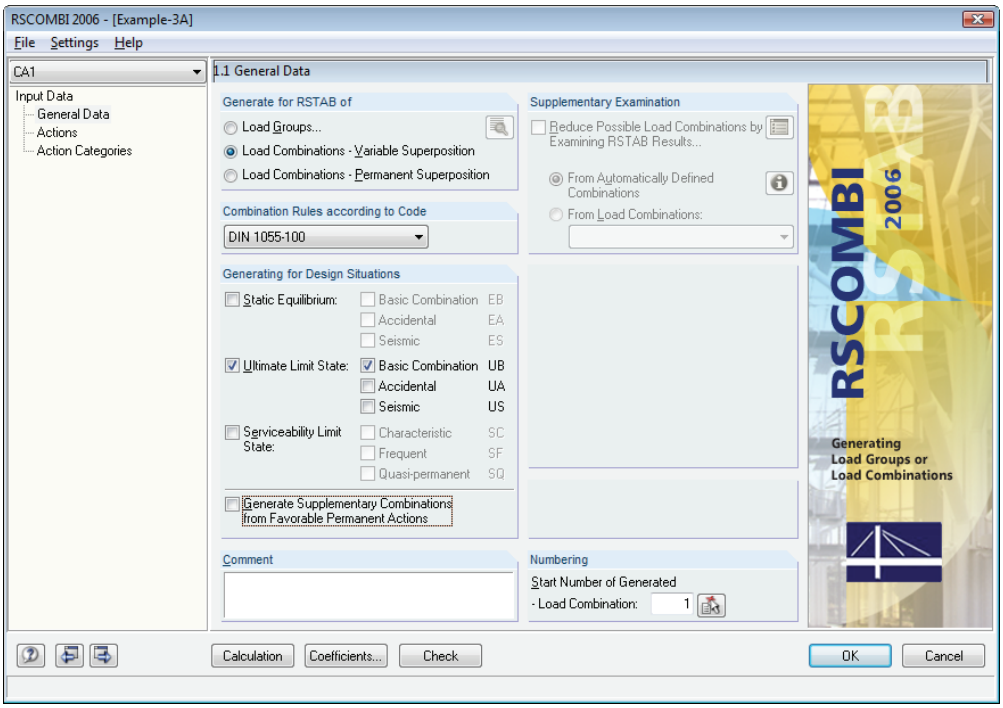

Figure 5.18: Mask 1.1 *General Data*: Generation of load combinations

Results of generation of load combinations

For the design situation 'Ultimate limit state - basic combination', three load combinations CO7 to CO9 are generated which are to be analyzed. These combinations are created according to formula 2.1 (see page 6).

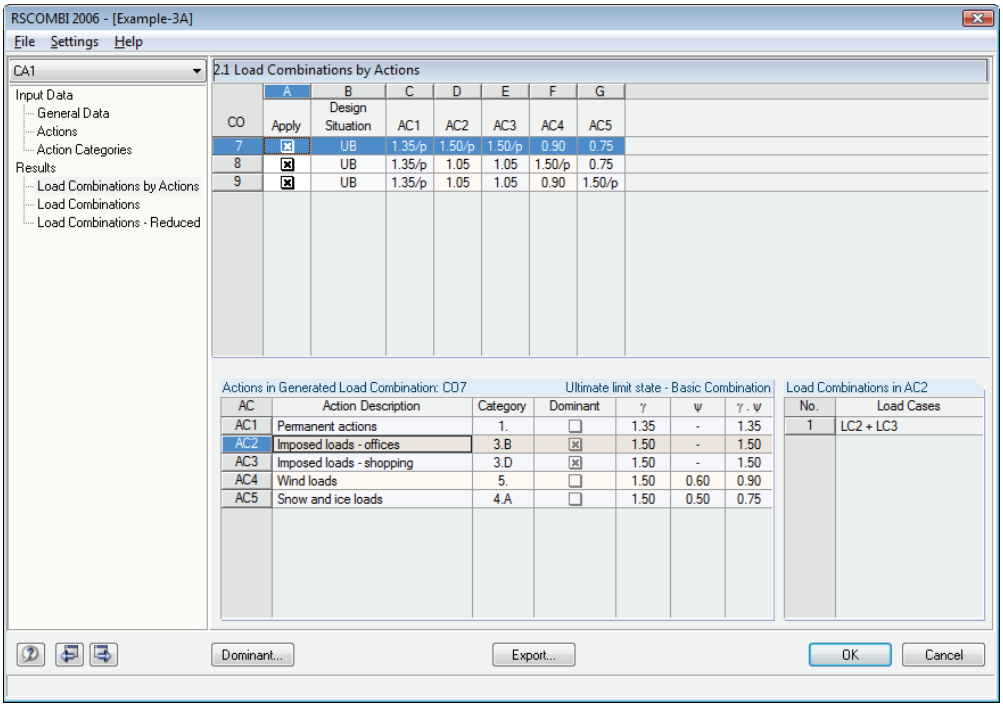

Figure 5.19: Mask 2.1 *Load Combinations by Actions*

The combinations CO1 to CO6 represent all possible combinations of load cases within the respective actions. In the lower part of mask 2.1 in Figure 5.19, you can see that the only possible internal load combination in action AC2 is the combination CO2 *LC2 + LC3*. If you click some different action, the internal combination for this action becomes visible.

Mask 2.2 differs from mask 2.1 mainly in the upper part, where actions are replaced by inner load combinations. If any inner load combinations are in brackets, then these inner combinations are in the relation *Alternative*.

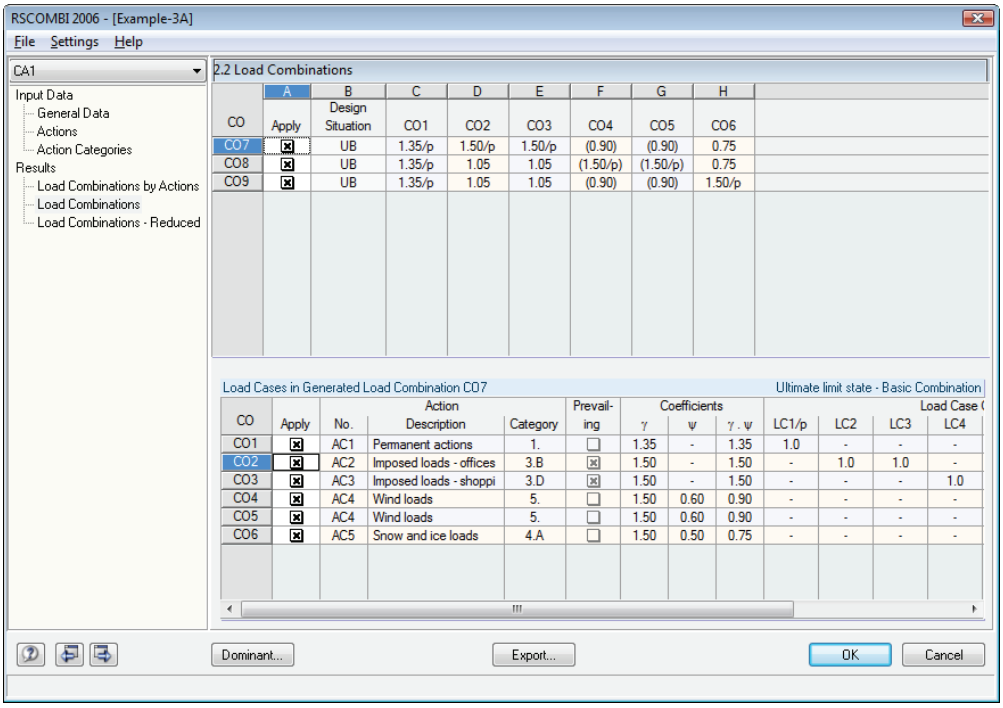

Figure 5.20: Mask 2.2 *Load Combinations*

The list of internal load combinations is displayed in the lower part of mask 2.2.

For example, the load combination CO7 is expressed as follows in mask 2.1 (Figure 5.19):

1.35AC1/p + 1.50AC2/p + 1.50AC3 + 0.90AC4 + 0.75AC5

If you replace AC1 by combination CO1, AC2 by CO2, AC3 by CO3, AC4 by CO4 or CO5, and AC5 by CO6, you get:

CO7: 1.35CO1/p + 1.50CO2/p + 1.50CO3/p + 0.90CO4 or 0.90CO5 + 0.75CO6

5.4 Skeleton Structure with Imperfections (DIN 1055-100)

Structure and loads

The skeleton structure from example 3 is again loaded by permanent loads, live loads of offices and shopping areas, wind and snow. Additionally, imperfections are included.

Load case	Action	Action category
LC1	AC1	permanent
LC2, LC3	AC2	imposed loads, 3.B - offices $\psi_0 = 0.70$, $\psi_1 = 0.50$, $\psi_2 = 0.30$
LC4, LC5	AC3	imposed loads, 3.D - shopping $\psi_0 = 0.70$, $\psi_1 = 0.70$, $\psi_2 = 0.60$
LC6 or LC7	AC4	5. - wind loads $\psi_0 = 0.60$, $\psi_1 = 0.50$, $\psi_2 = 0$
LC8	AC5	4.A - snow and ice loads - sites at altitude < 1000 m $\psi_0 = 0.50$, $\psi_1 = 0.20$, $\psi_2 = 0$
LC9, LC10		imperfections

Table 5.5: Load cases and actions

Load groups are to be generated for the design situation 'Ultimate limit state - basic combination' according to DIN 1055-100.

Input data

In masks 1.1, 1.2, and 1.3, you enter the same input data as in example 3.

When you open mask 1.4, the two imperfection-type load cases LC9 and LC10 are shown.

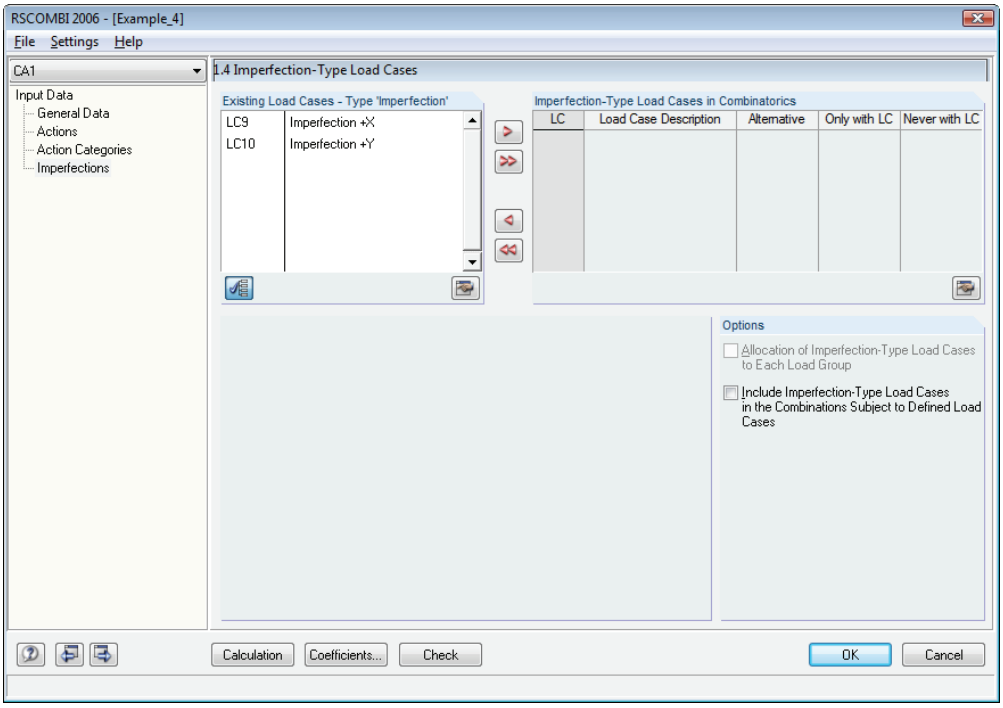

Figure 5.21: Mask 1.4 *Imperfections*

In order to consider the load cases LC9 and LC10 for the generated load groups, transfer them to the list *Imperfection-Type Load Cases in Combinations* by using the arrow. The imperfections LC9 and LC10 can never act simultaneously, hence the same description has to be applied in the column *Alternative*.

Load groups are calculated according to the second order theory. Therefore, every load group should contain one imperfection. For this reason, select the option *Allocation of imperfection-type load cases to each load group.*

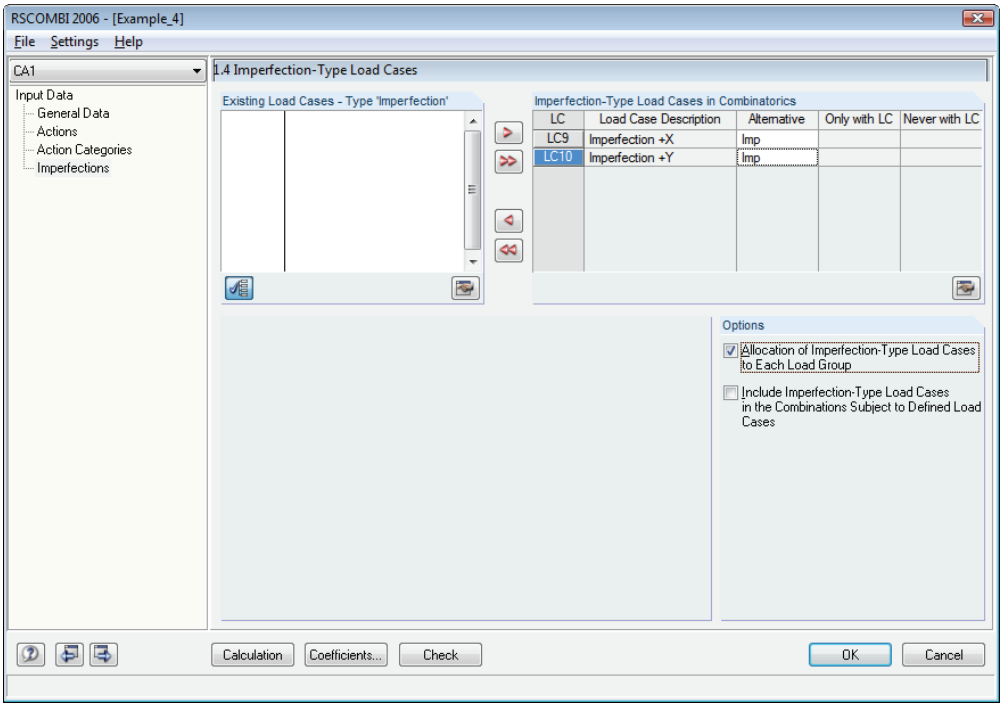

Figure 5.22: Mask 1.4 *Imperfections*, LC9 and LC10 in a combination

Results

For the design situation 'Ultimate limit state - basic combination', 406 load groups are generated according to formula 2.1 (see page 6). These are listed in mask 2.1 as follows.

2.1 Load Groups by Actions

No.	A Apply	B Generated Load Groups	C Design Situation	D AC1	E AC2	F AC3	G AC4	H AC5
1	☒	LG1 .. 2	UB	1.35	-	-	-	-
2	☒	LG3 .. 8	UB	1.35	1.50	-	-	-
3	☒	LG9 .. 26	UB	1.35	1.50	1.50	-	-
4	☒	LG27 .. 62	UB	1.35	1.50	1.50	0.90	-
5	☒	LG63 .. 98	UB	1.35	1.50	1.50	0.90	0.75
6	☒	LG99 .. 116	UB	1.35	1.50	1.50	-	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 .. 164	UB	1.35	-	1.50	0.90	-
12	☒	LG165 .. 176	UB	1.35	-	1.50	0.90	0.75
13	☒	LG177 .. 182	UB	1.35	-	1.50	-	0.75
14	☒	LG183 .. 186	UB	1.35	-	-	1.50	-
15	☒	LG187 .. 198	UB	1.35	1.05	-	1.50	-
16	☒	LG199 .. 234	UB	1.35	1.05	1.05	1.50	-
17	☒	LG235 .. 270	UB	1.35	1.05	1.05	1.50	0.75
18	☒	LG271 .. 282	UB	1.35	1.05	-	1.50	0.75
19	☒	LG283 .. 294	UB	1.35	-	1.05	1.50	-
20	☒	LG295 .. 306	UB	1.35	-	1.05	1.50	0.75
21	☒	LG307 .. 310	UB	1.35	-	-	1.50	0.75
22	☒	LG311 .. 312	UB	1.35	-	-	-	1.50
23	☒	LG313 .. 318	UB	1.35	1.05	-	-	1.50
24	☒	LG319 .. 336	UB	1.35	1.05	1.05	-	1.50
25	☒	LG337 .. 372	UB	1.35	1.05	1.05	0.90	1.50
26	☒	LG373 .. 384	UB	1.35	1.05	-	0.90	1.50
27	☒	LG385 .. 390	UB	1.35	-	1.05	-	1.50
28	☒	LG391 .. 402	UB	1.35	-	1.05	0.90	1.50
29	☒	LG403 .. 406	UB	1.35	-	-	0.90	1.50

Figure 5.23: Mask 2.1 *Load Groups by Actions* (overall view)

If you compare these results with those of the previous example 3 (Figure 5.16), you will notice that the number of generated load groups was duplicated. This is due to the fact that an imperfection was allocated to every load group, once as LC9 and once as LC10.

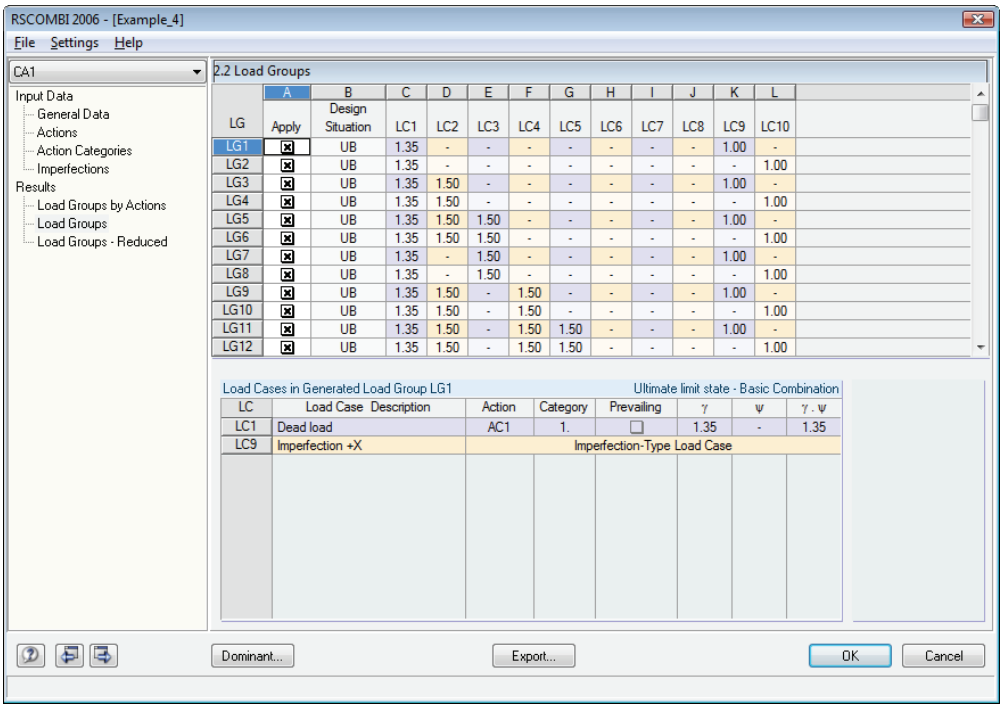

Figure 5.24: Mask 2.2 *Load Groups*

Note

Sometimes you know in advance that imperfections belong to certain load cases and it is pointless to connect them with other load cases. In this example, load case LC6 includes wind in direction +X and LC7 wind in direction +Y. The imperfection in LC9 is defined as inclination in direction +X and the imperfection in LC10 as inclination in direction +Y. Therefore it is not suitable to combine LC6 and LC10 or LC7 and LC9 in load groups. These groups will not be decisive.

In RSCOMBI, you can use this fact to reduce the number of generated load groups: Select the check box *Include imperfection-type load cases in combinations subject to defined load cases* in mask 1.4.

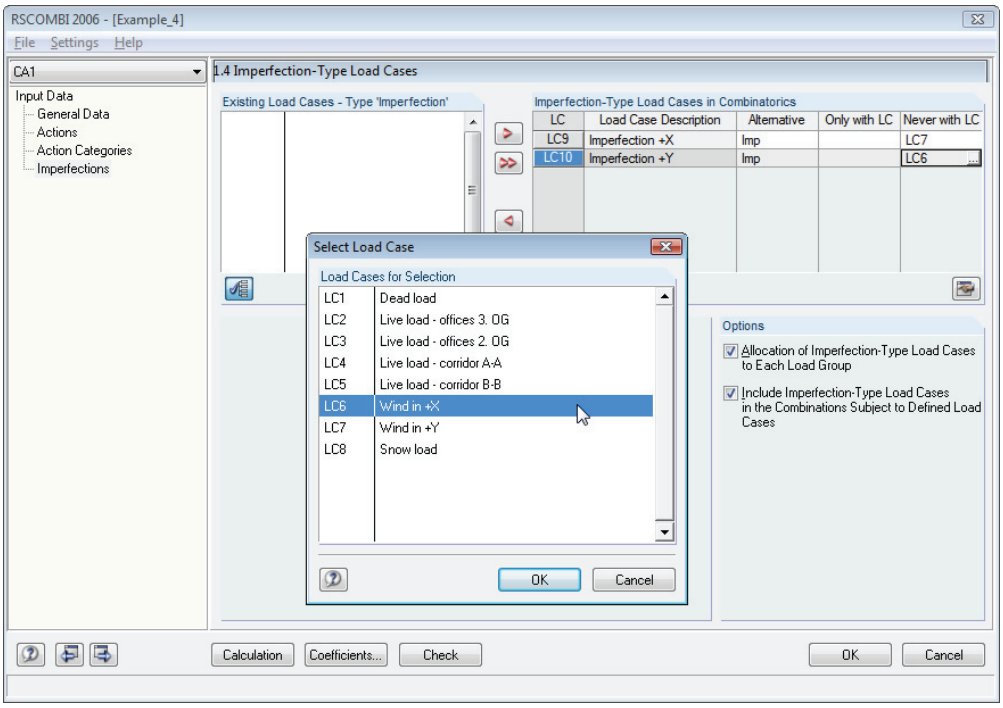

Figure 5.25: Mask 1.4 *Imperfections*, check boxes in the *Options* section

If you run the generation of load groups again now, only 250 load groups will be created instead of 406.

5.5 Frame (DIN 18800)

Structure and loads

The frame is loaded by permanent load, two variable loads and two accidental loads.

Load case	Action	Action category
LC1	AC1	permanent
LC2, LC3, LC4	AC2	variable (imposed loads)
LC5	AC3	variable (traffic loads)
LC6	AC4	accidental
LC7	AC5	accidental

Table 5.6: Load cases and actions

Load groups are to be generated for all design situations according to DIN 18800.

Input data

In the mask 1.1 *General Data*, you select that **load groups** are to be generated according to **DIN 18800**. Tick **all design situations**.

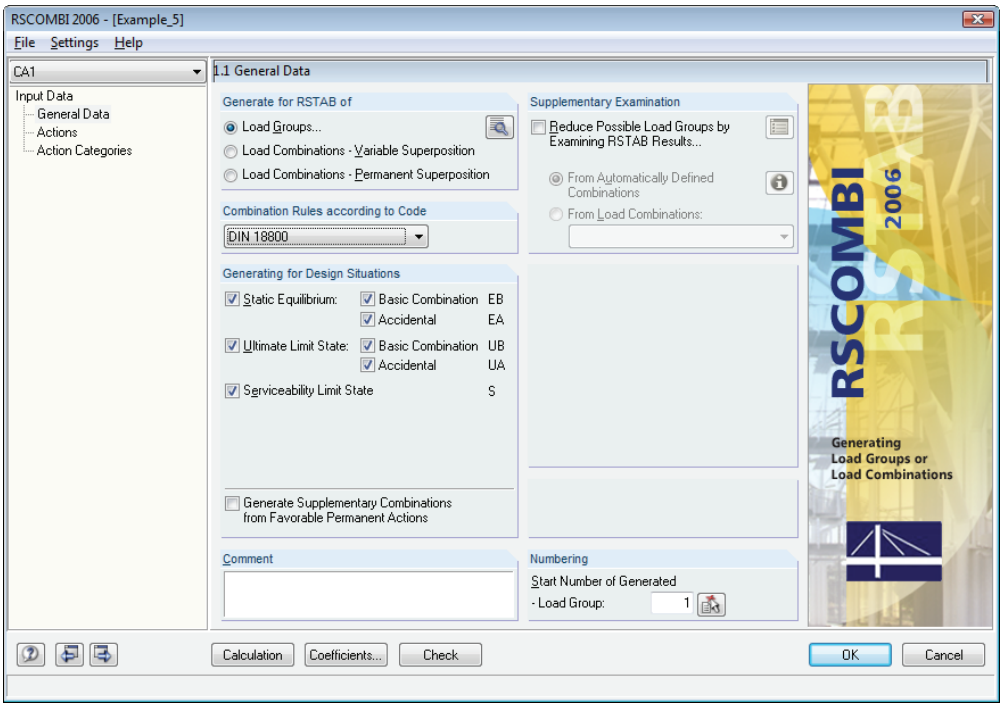

Figure 5.26: Mask 1.1 *General Data*

When you open mask 1.2, action **AC1** is created automatically and load case **LC1** is allocated to it. Other load cases defined in RSTAB are displayed in the list *Existing Load Cases*.

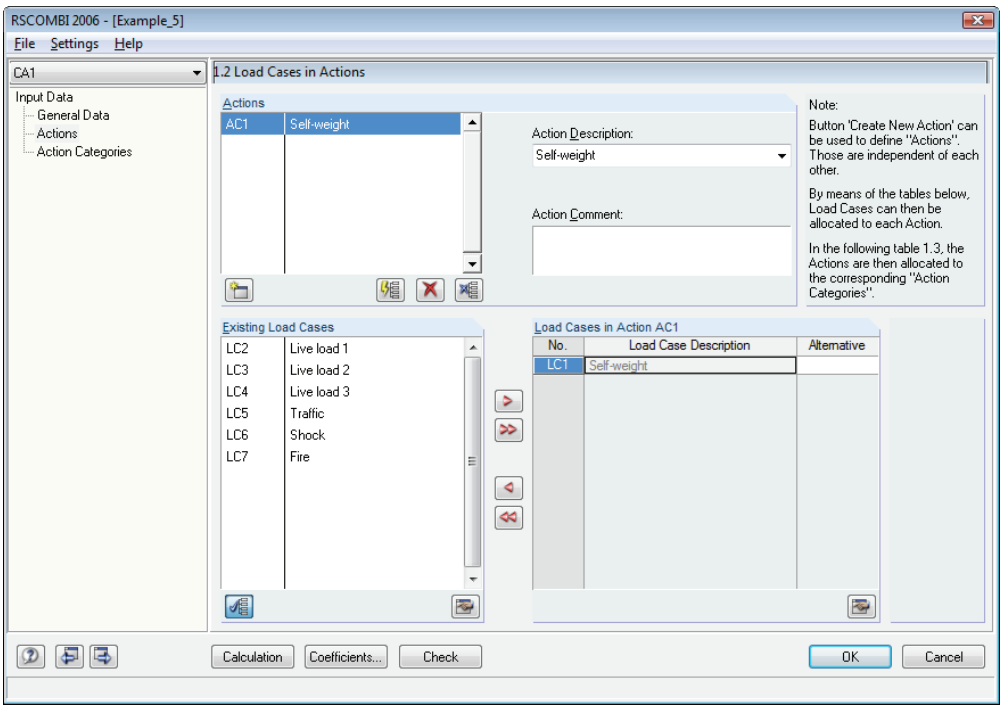

Figure 5.27: Mask 1.2 *Actions*

The actions AC2 to AC5 are created by using the button [Create New Action]. Then, the corresponding load cases are allocated.

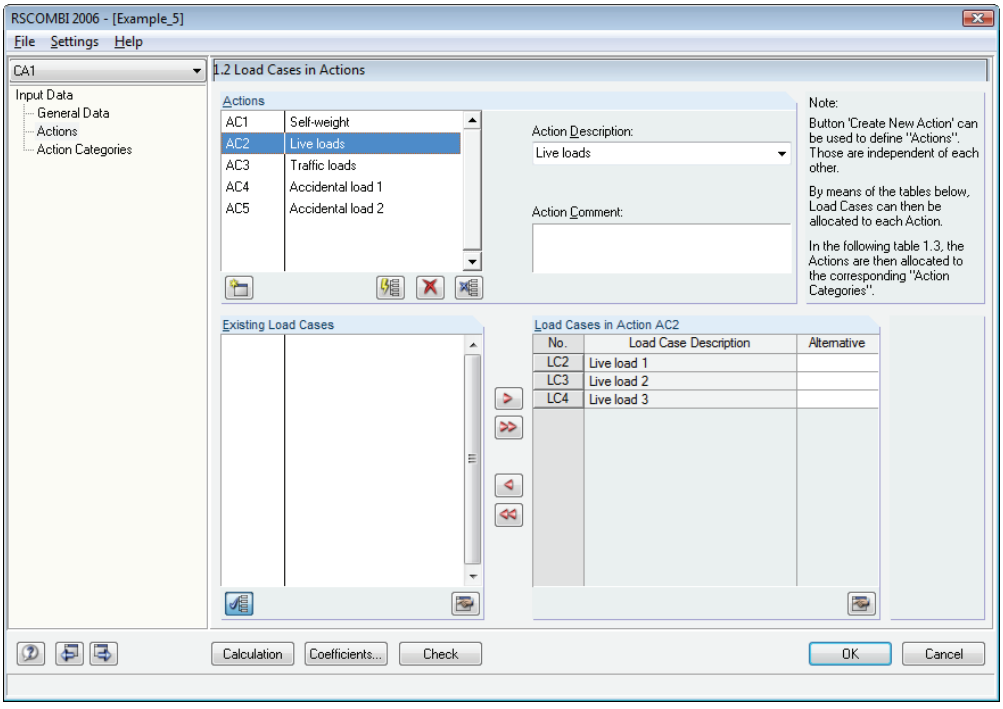

Figure 5.28: Actions with allocated load cases

The actions are then allocated to individual categories in mask 1.3 *Action Categories*.

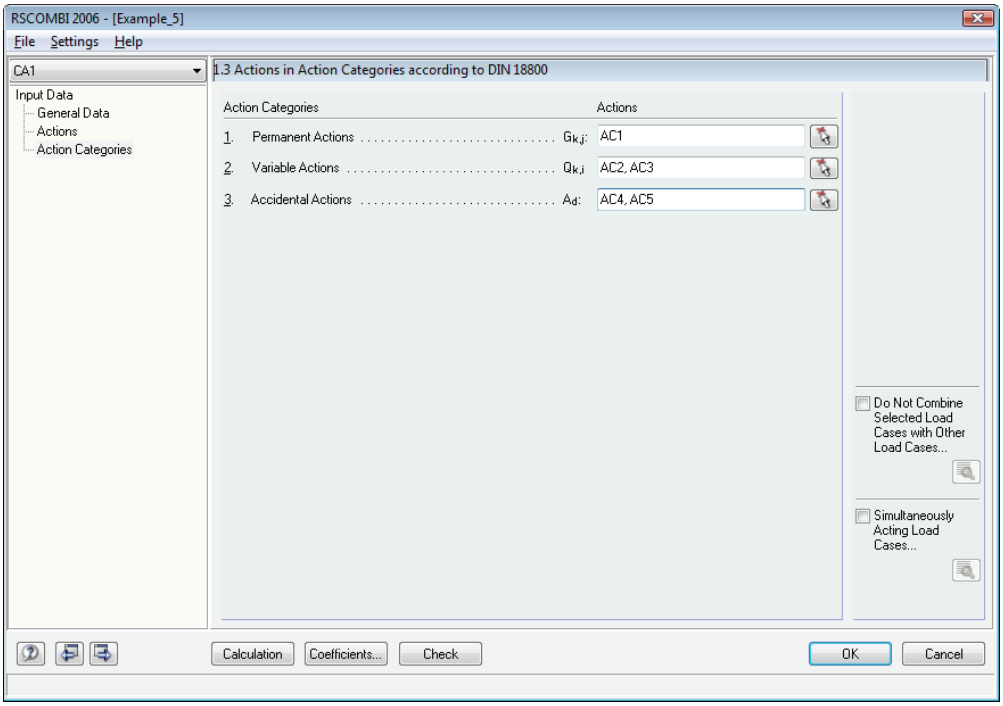

Figure 5.29: Mask 1.3 *Action Categories*

As there haven't been defined any imperfections for this example in RSTAB, the input is complete.

Results

In mask 2.1, 128 load groups are listed as follows:

- 16 load groups for the situation 'Ultimate limit state - basic combination' (UB, LG1 - LG16, see formula 2.7 and formula 2.8)
- 32 load groups for the situation 'Ultimate limit state - accidental' (UA, LG17 - LG48, see formula 2.9)
- 32 load groups for the situation 'Static equilibrium - basic combination' (EB, LG49 - LG80, see formula 2.7 and formula 2.8)
- 32 load groups for the situation 'Static equilibrium - accidental' (EA, LG81 - LG112, see formula 2.9)
- 16 load groups for the situation 'Serviceability limit state' (S, LG113 - LG128, see formula 2.7)

2.1 Load Groups by Actions

No.	A Apply	B Generated Load Groups	C Design Situation	D AC1	E AC2	F AC3	G AC4	H AC5
1	☒	LG1	UB	1.35	-	-	-	-
2	☒	LG2 .. 8	UB	1.35	1.50	-	-	-
3	☒	LG9 .. 15	UB	1.35	1.35	1.35	-	-
4	☒	LG16	UB	1.35	-	1.50	-	-
5	☒	LG17	UA	1.00	-	-	1.00	-
6	☒	LG18	UA	1.00	-	-	-	1.00
7	☒	LG19 .. 25	UA	1.00	0.90	-	1.00	-
8	☒	LG26 .. 32	UA	1.00	0.90	0.90	1.00	-
9	☒	LG33	UA	1.00	-	0.90	1.00	-
10	☒	LG34 .. 40	UA	1.00	0.90	-	-	1.00
11	☒	LG41 .. 47	UA	1.00	0.90	0.90	-	1.00
12	☒	LG48	UA	1.00	-	0.90	-	1.00
13	☒	LG49	EB	1.10	-	-	-	-
14	☒	LG50 .. 56	EB	1.10	1.50	-	-	-
15	☒	LG57 .. 63	EB	1.10	1.35	1.35	-	-
16	☒	LG64	EB	1.10	-	1.50	-	-
17	☒	LG65	EB	0.90	-	-	-	-
18	☒	LG66 .. 72	EB	0.90	1.50	-	-	-
19	☒	LG73 .. 79	EB	0.90	1.35	1.35	-	-
20	☒	LG80	EB	0.90	-	1.50	-	-
21	☐	LG81	EA	1.00	-	-	1.00	-
22	☐	LG82	EA	1.00	-	-	-	1.00
23	☐	LG83 .. 89	EA	1.00	0.90	-	1.00	-
24	☐	LG90 .. 96	EA	1.00	0.90	0.90	1.00	-
25	☐	LG97	EA	1.00	-	0.90	1.00	-
26	☐	LG98 .. 104	EA	1.00	0.90	-	-	1.00
27	☐	LG105 .. 111	EA	1.00	0.90	0.90	-	1.00
28	☐	LG112	EA	1.00	-	0.90	-	1.00
29	☒	LG113	S	1.00	-	-	-	-
30	☒	LG114 .. 120	S	1.00	1.00	-	-	-
31	☒	LG121 .. 127	S	1.00	1.00	1.00	-	-
32	☒	LG128	S	1.00	-	1.00	-	-

Figure 5.30: Mask 2.1 *Load Groups by Actions* (an overall view)

5.6 Girder Grillage (EN 1990)

Structure and loads

The girder grillage is loaded by permanent load, live load, traffic load, and snow and wind loads.

Load case	Action	Action category
LC1	AC1	permanent
LC2, LC3, LC4	AC2	imposed load, 3.D - shopping
LC5	AC3	traffic load, 3.F - vehicle weight < 30 kN
LC6	AC4	snow and ice loads - other CEN members - sites at altitude over 1000 m
LC7 or LC8	AC5	wind loads

Table 5.7: Load cases and actions

Load groups are to be generated for the design situation 'Ultimate limit state - basic combination' according to EN 1990 CEN.

Input data

In the mask 1.1 *General Data*, select that **load groups** are to be generated according to **EN 1990** for the design situation **Ultimate limit state - basic combination**. To economize on material, the combination rule according to **formulas 6.10 and 6.10b** is to be applied. Formulas 6.10 and 6.10b in EN 1990 correspond to Formula 2.11 and Formula 2.12 in this manual (see page 9).

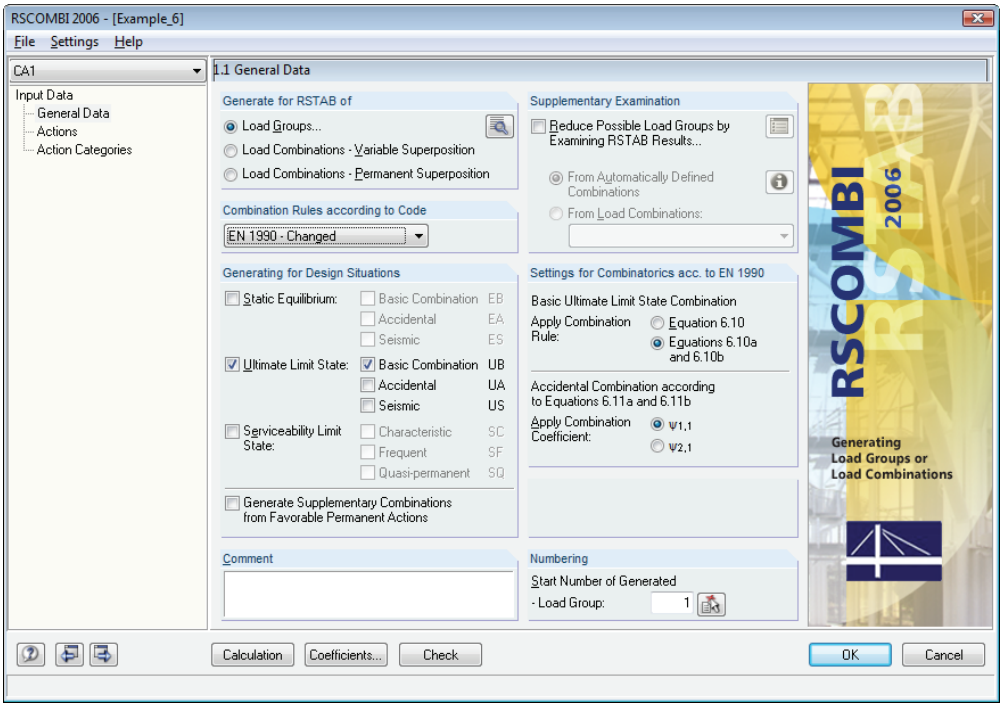

Figure 5.31: Mask 1.1 *General Data*

When you open mask 1.2, the action **AC1** is created automatically and load case **LC1** is allocated to it. The remaining load cases that have been defined in RSTAB are displayed in the section *Existing Load Cases.*

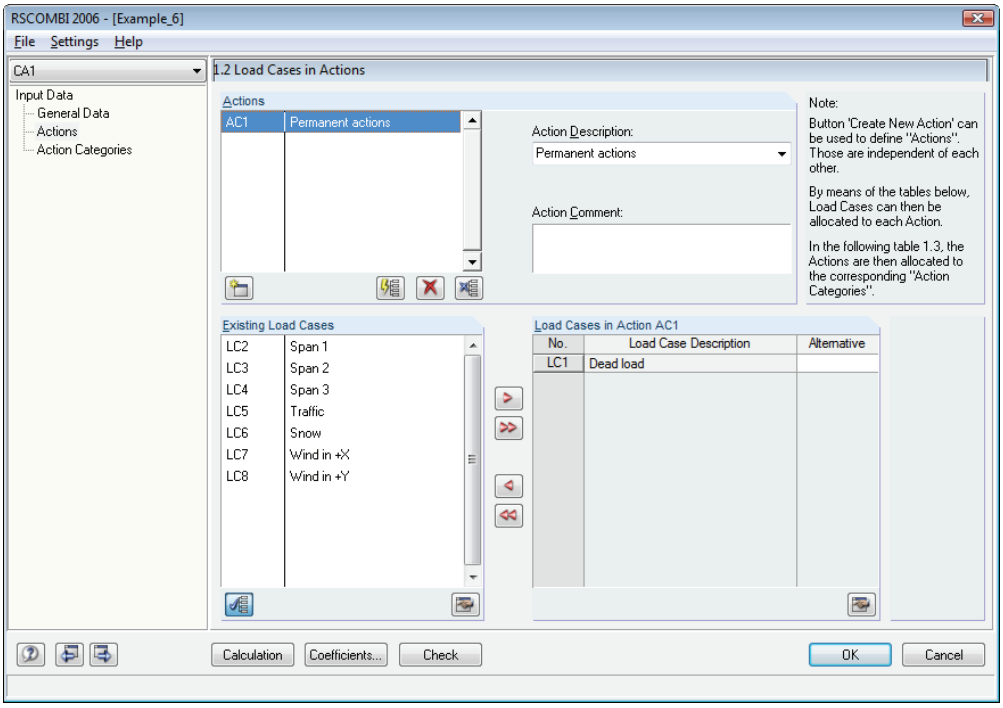

Figure 5.32: Mask 1.2 *Actions*

The actions AC2 to AC5 can now be created by using the button [Create New Action].

When allocating LC7 and LC8 to action AC5, you must pay attention to the mutual exclusivity of these two load cases. Thus, enter the same description in the *Alternative* column.

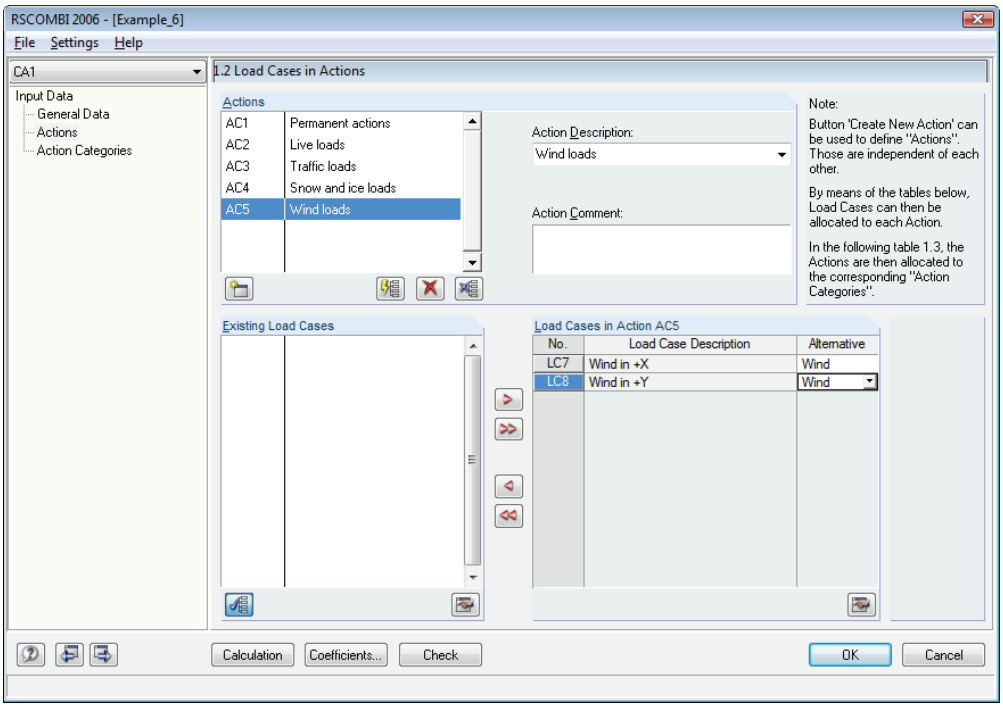

Figure 5.33: Actions with allocated load cases

The actions can then be allocated to corresponding categories in mask 1.3.

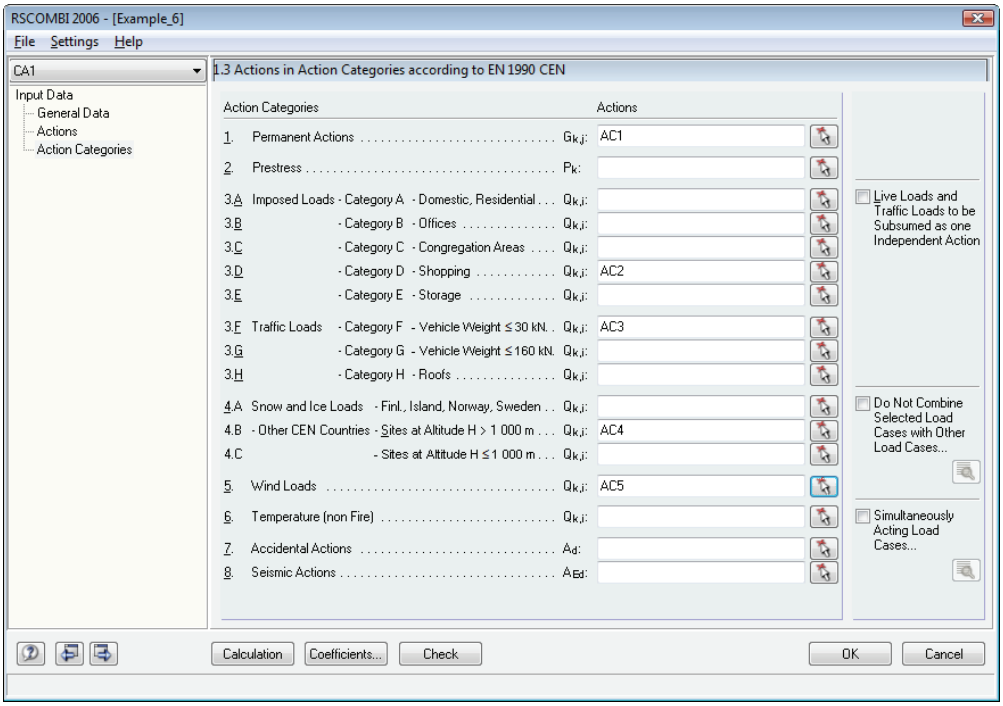

Figure 5.34: Mask 1.3 *Action Categories*

As there aren't any imperfections to be considered, the input is complete.

Results in RSCOMBI

In mask 2.1, 341 load groups are displayed.

The load groups LG1 to LG96 were generated according to formula 2.11, the load groups LG97 to LG341 according to formula 2.12 (see page 9).

2.1 Load Groups by Actions

No.	A Apply	B Generated Load Groups	C 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
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 5.35: Mask 2.1 *Load Groups by Actions* (overall view)

5.7 Column (ASCE 7)

Structure and loads

A concrete column is loaded by five load cases. Every load case represents an individual action. The load cases and column have already been defined in RSTAB.

Load case	Action	Action category
LC1	D	dead load
LC2	L	live load
LC3	W	wind load
LC4	Fa	flood load
LC5	E	earthquake load

Table 5.8: Load cases and actions as specified in ASCE 7

In RSCOMBI, load groups are to be generated according to ASCE 7-02, section 2.3 (LRFD), that is *Combining factored loads using strength design*, and consequently also according to section 2.4 (ASD), that is *Combining factored loads using allowable stress design.* Then all results are to be exported to RSTAB.

Input data

In the mask 1.1 *General Data*, you choose that **load groups** are to be generated according to **ASCE 7**, Section 2.3 (LRFD). Due to the fact that flood load is to be considered, select the option *Load combinations including flood load according to 2.3.3 or 2.4.2.*

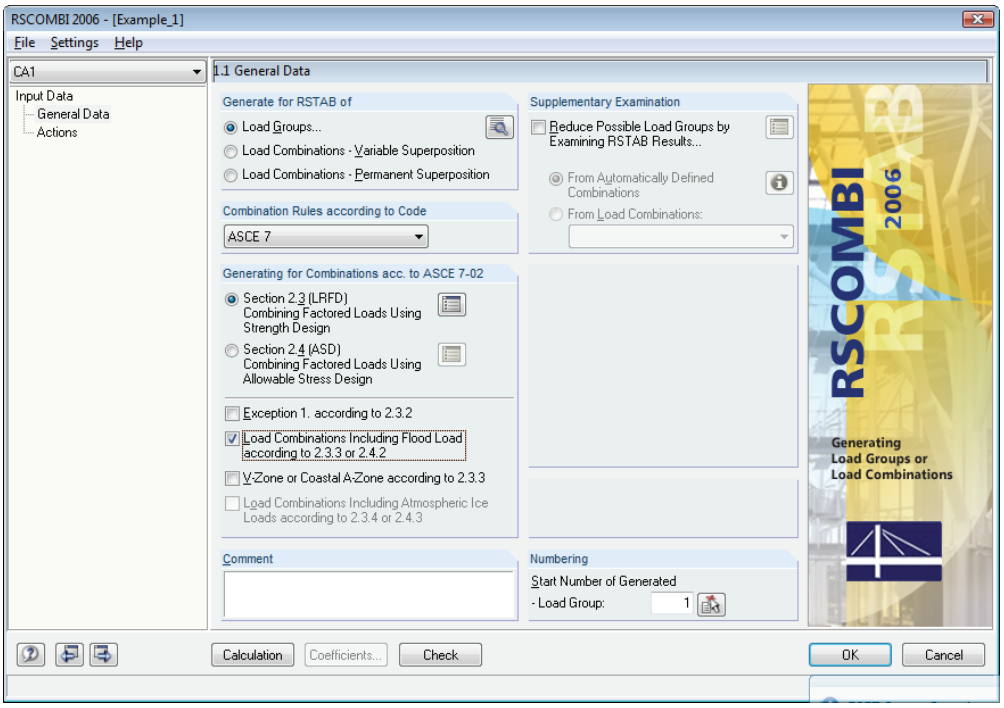

Figure 5.36: Mask 1.1 *General Data*

For the American ASCE 7 standard, the mask 1.3 *Action Categories* does not exist. All action categories are listed in the mask 1.2 *Load Cases in Actions*. In the lower tables of this mask, you assign existing load cases to available actions.

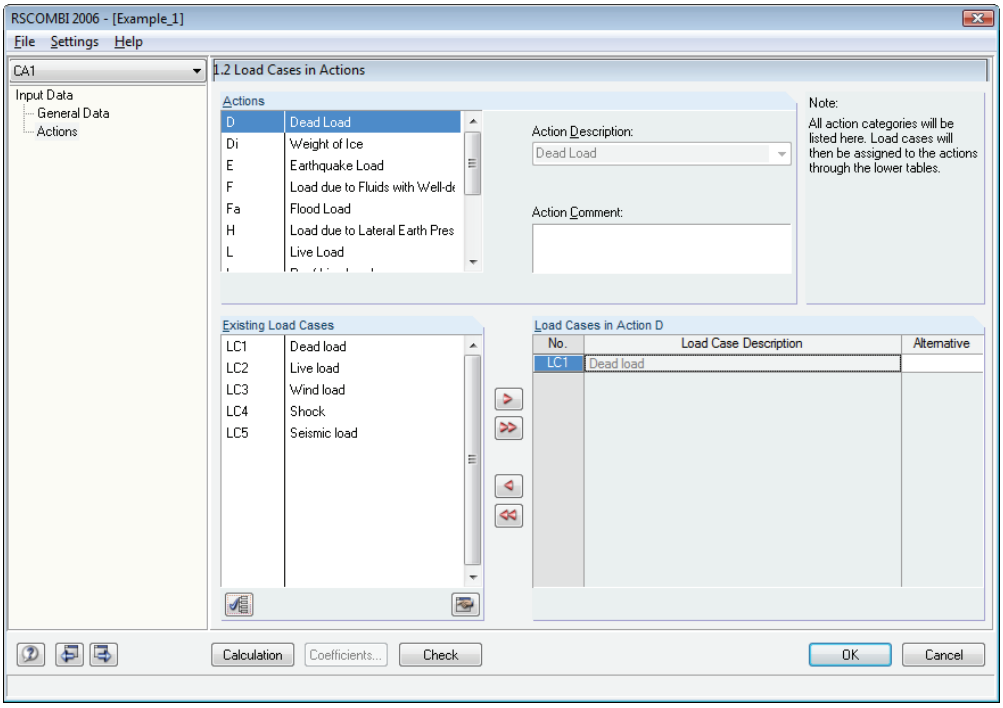

Figure 5.37: Mask 1.2 *Load Cases in Actions* with all specified actions according to ASCE 7 in section *Actions*

Every load case represents one action. You can also insert action descriptions in the box *Action comment.* The input is now complete.

Results for the strength design (LRFD)

By combining factored loads using the strength design, seven load groups are generated.

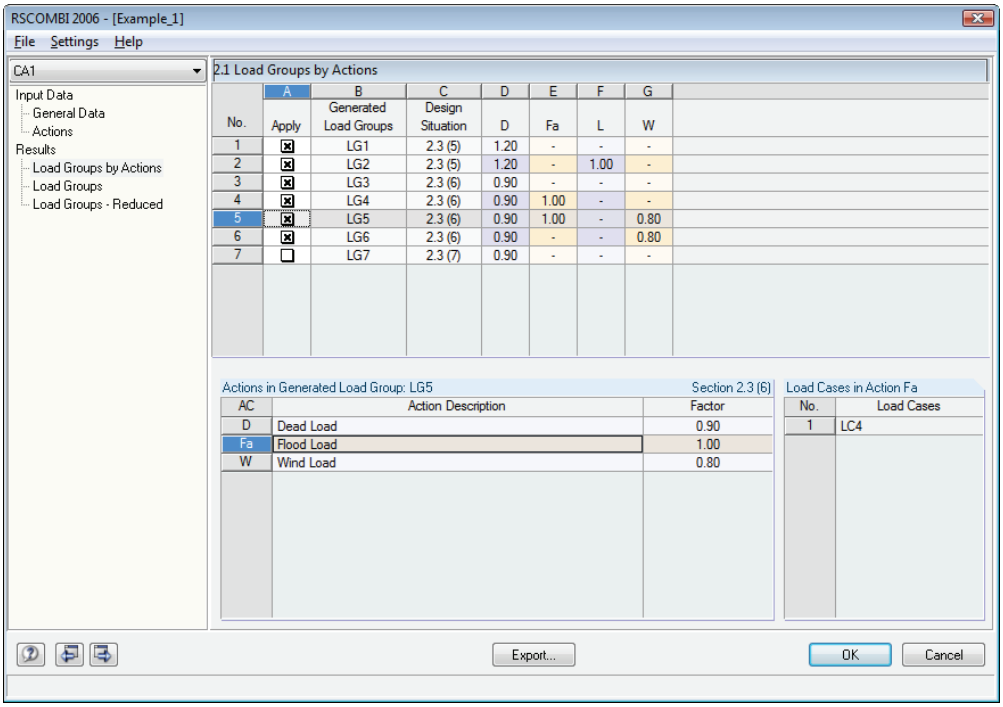

Figure 5.38: Mask 2.1 *Load Groups by Actions* – results for strength design (LRFD)

In mask 2.2, you can find the detailed results. These are sorted by *load cases* instead of *actions*.

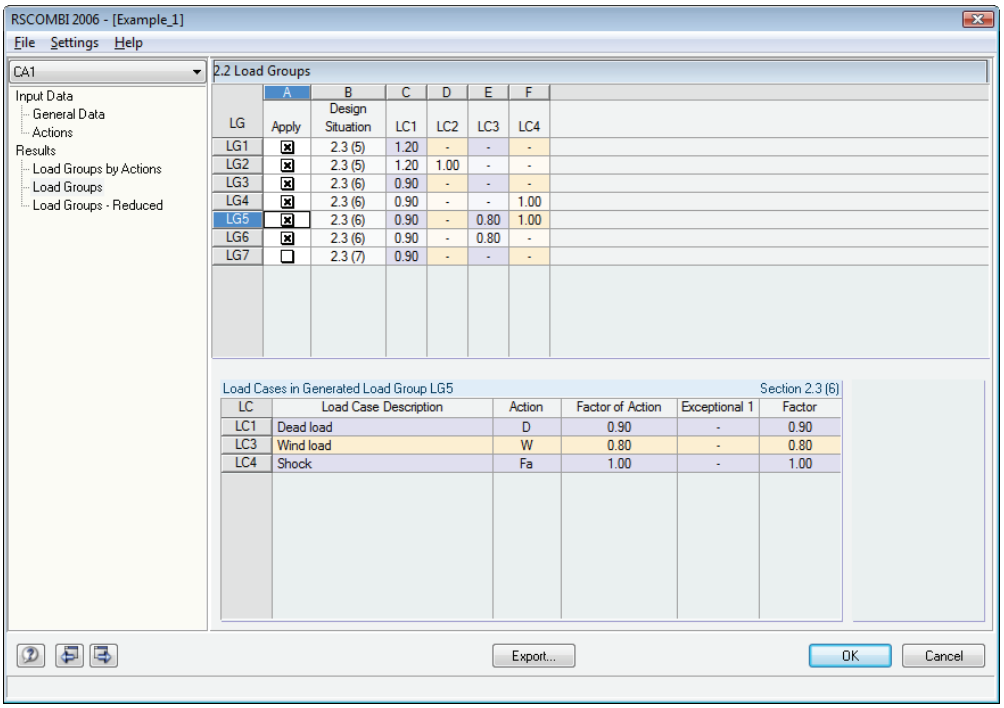

Figure 5.39: Mask 2.2 *Load Groups*

Results for the allowable stress design (ASD)

By combining factored loads using the allowable stress design, five load groups are generated.

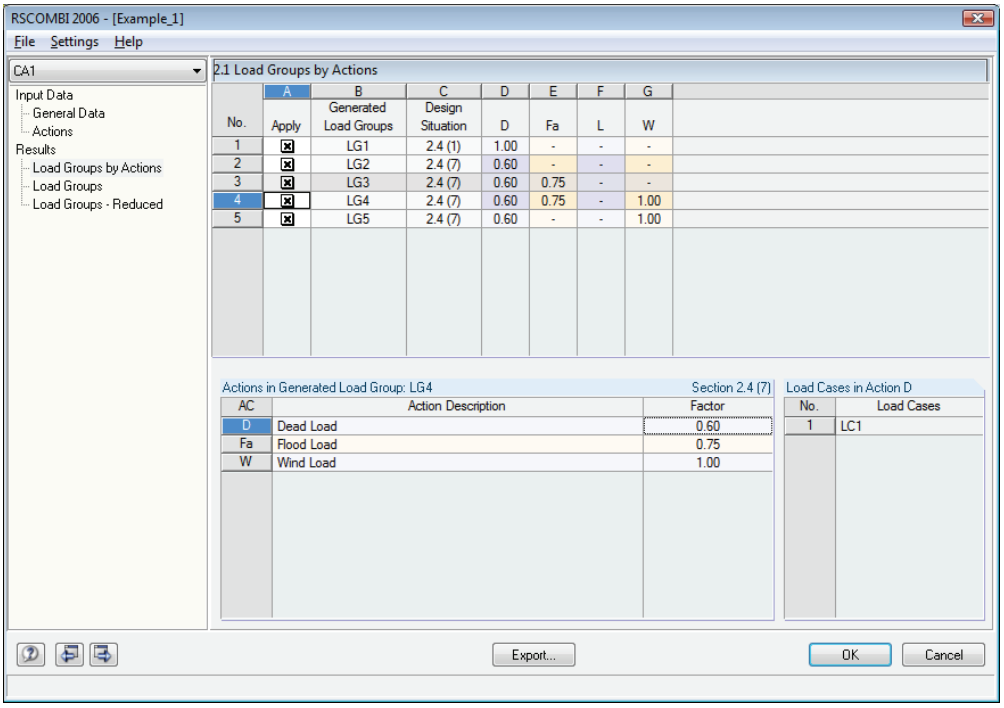

Figure 5.40: Mask 2.1 *Load Groups by Actions* – results for allowable stress design (ASD)

In case of the strength design, you can export seven load groups and also one 'Either-or' combination to RSTAB. For the latter, you have to select this option in the section *Either/or Load Combination* in the *Export* dialog box.

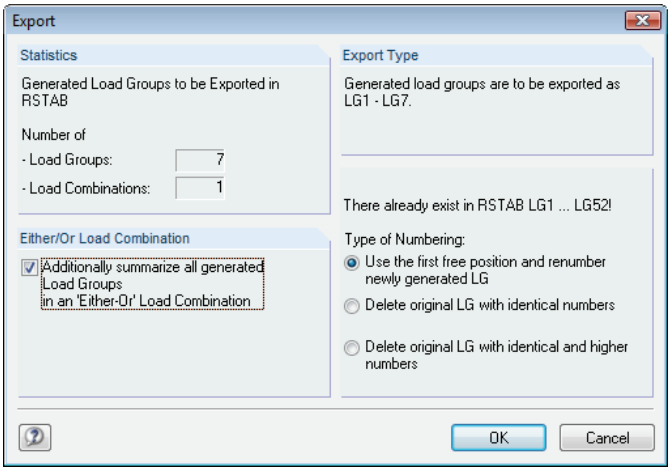

Figure 5.41: Dialog box *Export* – strength design (LRFD)

In case of the allowable stress design, five load groups and one load combination can be exported to RSTAB.

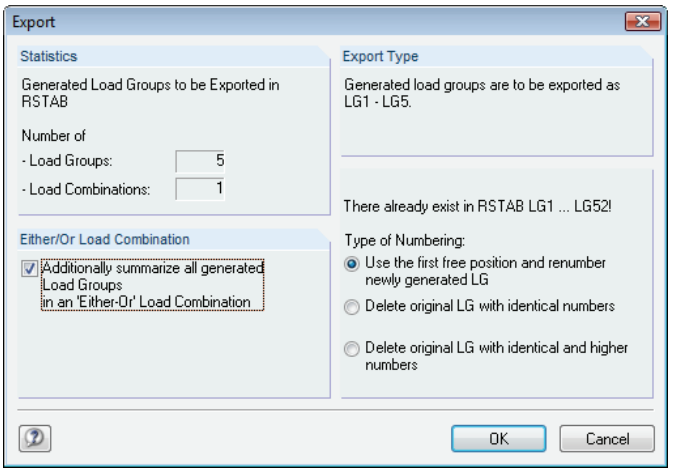

Figure 5.42: Dialog box *Export* – allowable stress design (ASD)

5.8 Framework Structure (CAN/CSA)

Structure and loads

A framework structure is loaded by dead load, live loads of offices and of shopping areas, and wind loads.

Load case	Action	Action category
LC1	D	Dead load
LC2, LC3, LC4, LC5	L	Live load
LC6, LC7	W	Wind load

Table 5.9: Load cases and actions

There are load groups and load combinations to be generated according to the Canadian standard CAN/CSA, clause 7.2.2 (without earthquake).

Input data for generation of load groups

In the mask 1.1 *General Data*, you decide that **load groups** are to be generated according to **CAN/CSA S16.1-94**, *Clause 7.2.2 (without earthquake)*.

In mask 1.2 *Load Cases in Actions*, all action categories are to be specified. You assign load cases to actions in the lower tables.

When allocating LC6 and LC7 to W, you must pay attention to the mutual exclusivity of these two load cases. Thus, enter the same description in the *Alternative* column

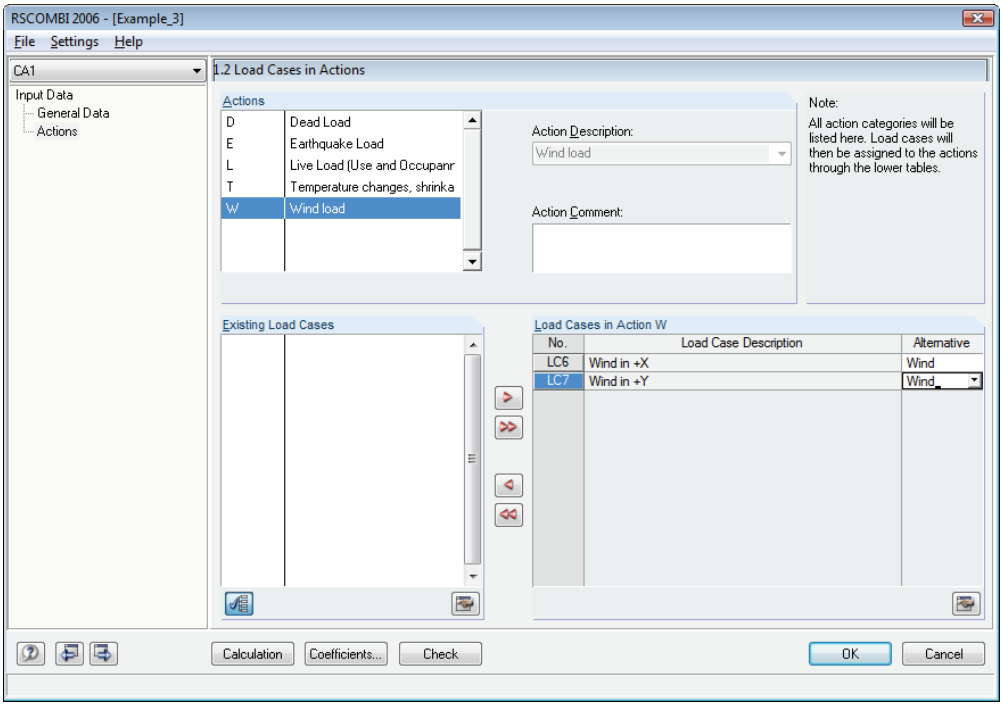

Figure 5.43: Mask 1.2 *Load Cases in Actions*

Results

48 load groups are generated for clause 7.2.2 of the CAN/CSA standard. In mask 2.1, they are listed as follows.

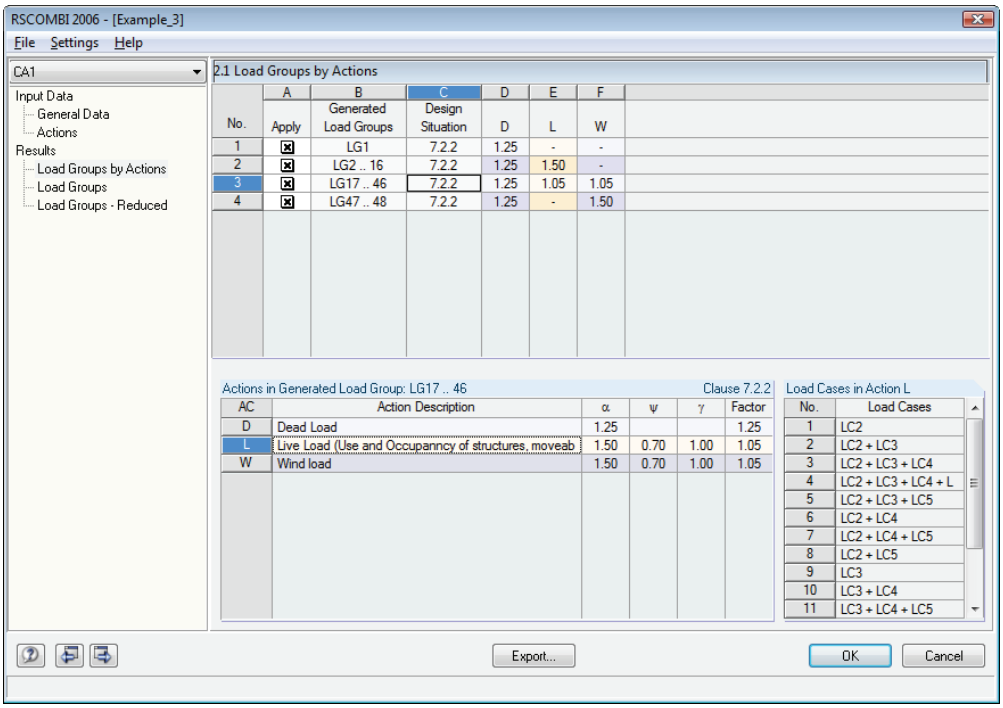

Figure 5.44: Mask 2.1 *Load Groups by Actions*

Input data for generation of load combinations

The input data differs from the previous entry in one thing only: in mask 1.1, you select the option **Load combinations - variable superposition** in section *Generate for RSTAB*.

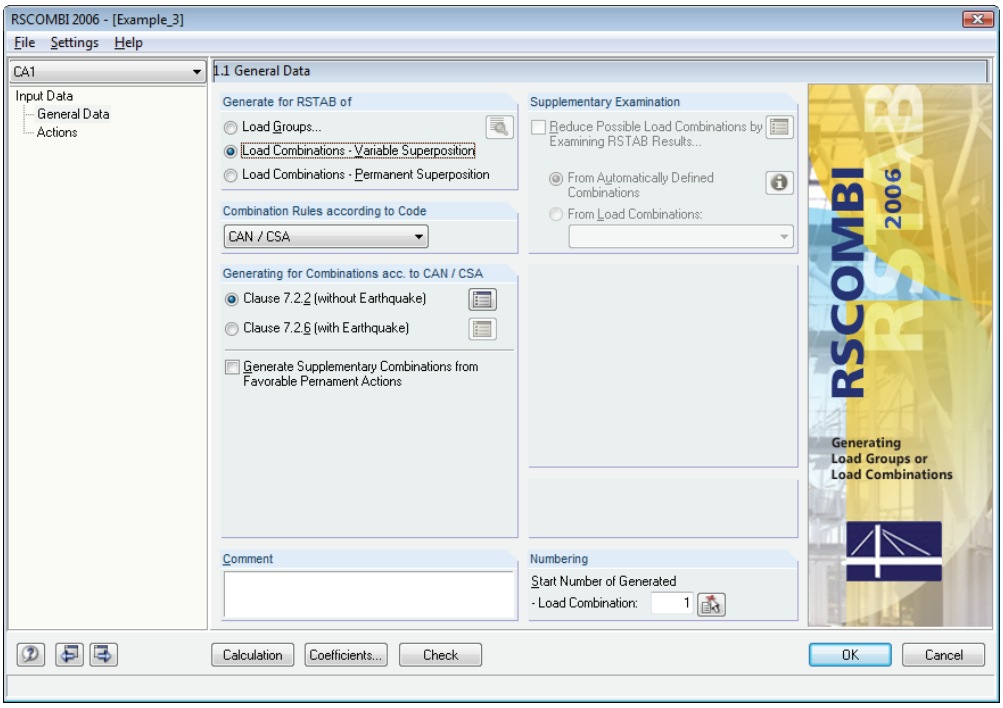

Figure 5.45: Mask 1.1 *General Data*: Generation of load combinations

Results of generation of load combinations

For the design situation according to clause 7.2.2 of the Canadian standard CAN/CSA, the three load combinations CO5 to CO7 are generated which are to be analyzed.

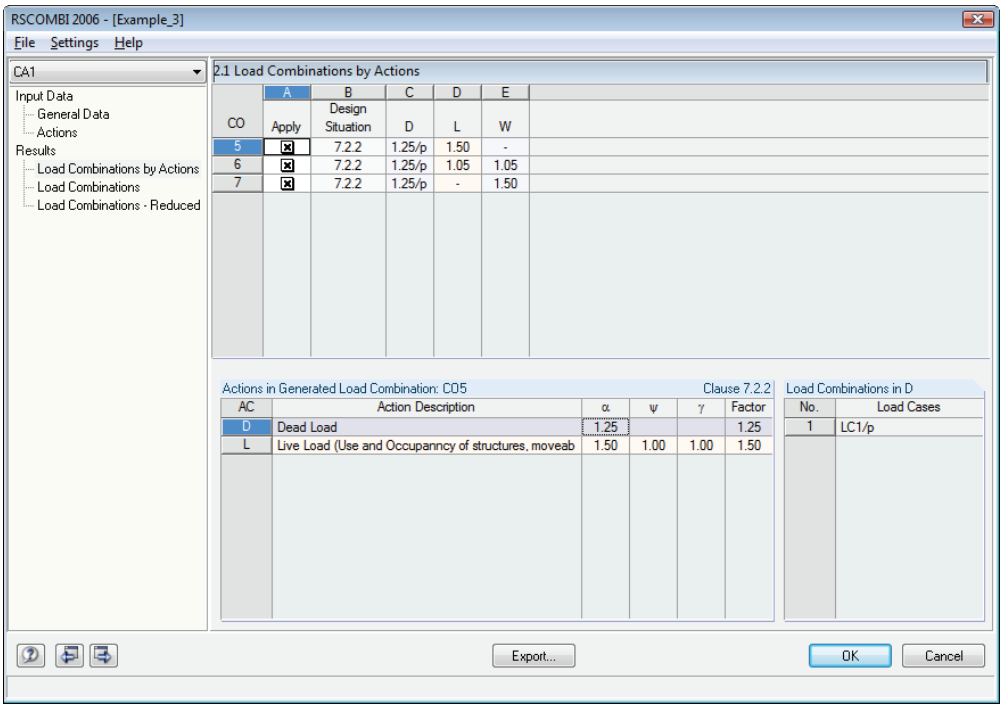

Figure 5.46: Mask 2.1 *Load Combinations by Actions*

The combinations CO1 to CO4 represent all possible combinations of load cases within the respective actions. In the lower part of mask 2.1 in Figure 5.46, you can see that there are two possible internal load combinations within combination CO5: *LC1/p* and *LC1/p+ LC3*. If you click some different combination, the internal combinations become visible.

A: Literature

[1] EN 1990 Basis of Structural Design (Eurocode).

[2] EN 1995 Design of Timber Structures (Eurocode 5).

[3] ASCE 7. Published in 2006 by the American Society of Civil Engineers.

[4] ACI 318-08. Published in January 2008 by the American Concrete Institute.

[5] CAN/CSA. Published by the Canadian Standards Association.

[6] IS 800 General Construction in Steel – Code of Practice. Published in December 2007 by Bureau of Indian Standards.

[7] DIN 1055-100 Einwirkungen auf Tragwerke. Published in March 2001

[8] DIN 18800 Stahlbauten. Published in November 1990

[9] Grünberg, J.: Grundlagen der Tragwerksplanung – Sicherheitskonzept und Bemessungsregeln für den konstruktiven Ingenieurbau. Erläuterungen zu DIN 1055-100, Published 2004