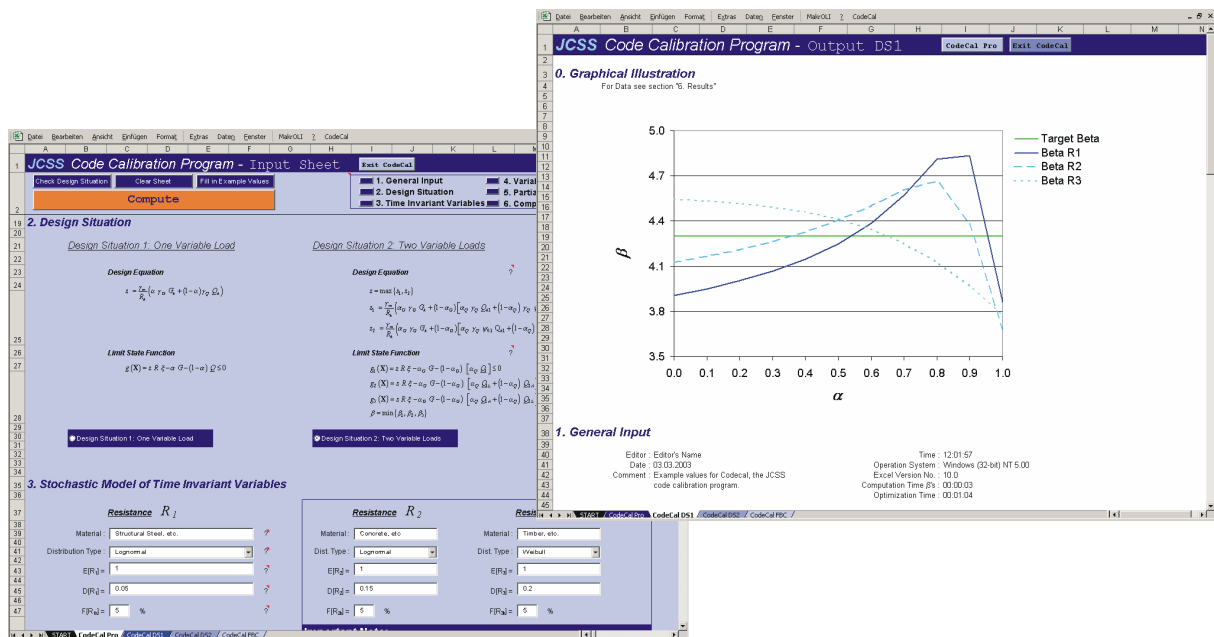


Tutorial for the JCSS Code Calibration Program

CodeCal



Michael Havbro Faber, Oliver Kübler & Jochen Köhler

Swiss Federal Institute of Technology
 Institute of Structural Engineering
 Group on Risk and Safety
 ETH – Hoenggerberg, HIL E 32.3
 CH – 8093 Zurich
 Tel.: +41 1 63 33117
 Fax.: +41 1 63 31064
 E-Mail: michael.faber@ethz.ch
 Web: www.ibk.baug.ethz.ch/Fa/

March 2003

1 Introduction

Modern structural design codes such as the EUROCODES provide a simple, economic and safe way for the design of civil engineering structures. Thereby, design codes not only facilitate the daily work of structural engineers but also optimize the resources of society. Traditionally, design codes take basis in design equations, from which the reliability verification of a given design may be easily performed by a simple comparison of resistances and loads and/or load effects. Due to the fact that loads and resistances are subject to uncertainties, design values for resistances and load effects are introduced in the design equations to ensure that the design is associated with an adequate level of reliability. Design values for resistances are introduced as a characteristic value of the resistance divided by a partial safety factor (typically larger than 1.0) and design values for load effects are introduced as characteristic values multiplied by a partial safety factor (typically larger than 1.0). Furthermore, in order to take into account the effect of simultaneously occurring variable load effects load combination factors (typically smaller than 1.0) are multiplied on one or more of the variable loads.

By means of structural reliability methods the safety formats of the design codes i.e. the design equations, characteristic values, partial safety factors and load combination factors may be chosen such that the level of reliability of all structures designed according to the design codes is homogeneous and independent of the choice of material and the prevailing loading, operational and environmental conditions. This process including the choice of the desired level of reliability or “target reliability” is commonly understood as “code calibration” this is described in Faber Sorensen (2003).

The present tutorial introduces the code calibration program CodeCal. This program is made available by the Joint Committee on Structural Safety (JCSS) and can be downloaded from its webpage at: www.jcss.ethz.ch. CodeCal takes basis in the Structural Reliability Analysis and the Load and Resistance Factor Design format (LRFD), which is used by EUROCODE. If the safety format and the stochastic variables have been defined, CodeCal evaluates for a given set of safety factors the reliability index using First Order Reliability Methods (FORM). Therefore, CodeCal uses the FORM. Using optimization methods CodeCal is also able to determine partial safety and load combination factors corresponding to a predefined safety level, whereby up to three materials can be considered at the same time. Within this tutorial, the features of CodeCal are described shortly and examples are provided illustrating its application.

2 Installation of CodeCal

2.1 Requirements:

CodeCal is a Microsoft Excel © based program. In order to enhance the computational performance, the program makes use of Fortran Dynamic Link Libraries. To run CodeCal, Microsoft Excel has to be installed on the computer system. The program was successfully tested for Excel 2000, Excel 2002, Windows 98, Windows 2000 and Windows XP. It can be obtained for free at the webpage of the Joint Committee on Structural Safety (JCSS) at www.jcss.ethz.ch.

2.2 Installation:

CodeCal consists of following files:

- CodeCal 03 - Tutorial.pdf
- CodeCal 03.xls
- CodeCal 03.dll
- dforrt.dll
- msvert.dll

"CodeCal 03 - Tutorial.pdf" is the CodeCal Tutorial you are currently reading. "CodeCal 03.xls" is the main file and has to be opened in order to start CodeCal. "CodeCal 03.dll", "dforrt.dll" and "msvcrt.dll" are required Fortran Dynamic Link Libraries containing the FORM and optimization routines for CodeCal.

These files can be downloaded from the JCSS homepage at www.jcss.ethz.ch. Please, create an empty directory and name it, e.g. "C:\CodeCal 03". Then copy the above listed files into this folder. It is important that all files are in the same directory! Please, notice that CodeCal does not require and therefore does not make any entry in your windows registry file.

2.3 Uninstallation:

In order to uninstall CodeCal, it is sufficient to delete the files, which are listed in section 2.2. Delete the folder in which they were stored, as well.

3 Start CodeCal

3.1 Start

To start CodeCal, please open the file "CodeCal 03.xls". Open it as you open other Excel files, e.g. by double clicking on "CodeCal 03.xls" in the Windows Explorer. The CodeCal start window is shown in Figure 1.

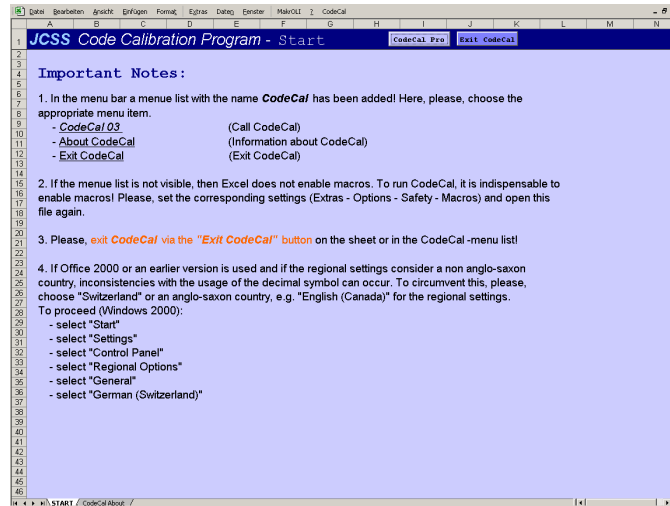


Figure 1. Start window of CodeCal.

If you run this program on Excel 2000 or an older version, you are additionally advised to pay attention to note 4.

Please, read all notes on the start window before continuing with the execution of CodeCal!

To proceed, please click onto the *CodeCal Pro* button on the top of the window or click onto the *CodeCal Pro* item in the *CodeCal menu list*. Then the *CodeCal Pro* sheet is activated. On the top of the sheet, there is the Command bar, which eases the use of CodeCal.

3.2 CodeCal Command Bar

The CodeCal command bar consists of the following buttons:

- Check Design Situation: Checks the currently applied design situation
- Clear Sheet: Clears all textboxes
- Fill in Example Values: Fills in the example values
- Compute: Launches the computation
- Exit CodeCal: Exit the CodeCal program
- Table of Content: Permits to navigate quickly through the sheet

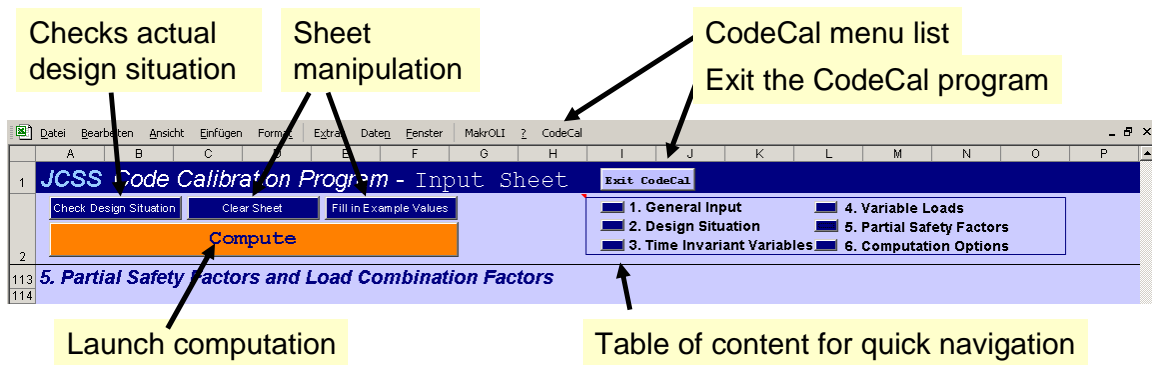


Figure 2. CodeCal Command Bar.

3.3 Additional Information

On the *CodeCal Pro* sheet you find question marks in connection with small red triangles. They indicate additional information. These remarks are shown, if you move the cursor to the question marks. They give you further background information or refer to further literature.

Design Situation 2: Two Variable Loads

Design Equation

$$z = \max \{ z_1, z_2 \}$$

$$z_1 = \frac{\gamma_m}{R_k} \left(\alpha_G \gamma_G G_k + (1 - \alpha_G) \left[\alpha_Q \gamma_Q Q_{k1} + (1 - \alpha_Q) \gamma_Q \psi_{01} Q_{k1} \right] \right)$$

$$z_2 = \frac{\gamma_m}{R_k} \left(\alpha_G \gamma_G G_k + (1 - \alpha_G) \left[\alpha_Q \gamma_Q Q_{k2} + (1 - \alpha_Q) \gamma_Q \psi_{01} Q_{k1} \right] \right)$$

? The Design Equation uses the format and notation according to Eurocode, see [6] & [7].
Choose "about CodeCal" in the CodeCal Menu bar to see the reference list.

Figure 3. Additional Information.

4 Examples

This section comprises selected examples. They illustrate the usage and features of CodeCal. They all use the example values of CodeCal. To fill in these values, press the *Fill in Example Value* button. Therefore, the following examples can be reproduced easily and quickly. The following list shows the five considered examples.

DS1-B-M1: Reliability indexes are evaluated for a given set of safety factors. This is done for design situation one (DS1), which considers a permanent load and a single variable load.

DS1-B-M2/3: Reliability indexes are evaluated for DS1 as DS1-B-M1 does; however, this example considers two or three materials.

DS1-O-M1/2/3: Partial safety factors are optimized for DS1 and for 1, 2 or 3 materials.

DS2-B-M1/2/3: Reliability indexes are evaluated for a given set of partial safety factors and one, two or three materials. This is done for design situation two (DS2), which considers a permanent load and two variable loads.

DS2-O-M1/2/3: Partial safety factors are optimized for DS2 and for 1, 2 or 3 materials.

4.1 DS1-B-M1: Reliability index evaluation for DS1 and one material

4.1.1 Description

Reliability indexes are evaluated for a given set of partial safety factors. It considers design situation one (DS1), which accounts a permanent and a variable load. CodeCal evaluates reliability indexes for varying ratios of permanent to total load (permanent plus variable load). The obtained reliability indexes are listed in a table and plotted in a diagram. This is done for a single material.

4.1.2 Data Input

The following figures show the inputted data, which are required for this example.

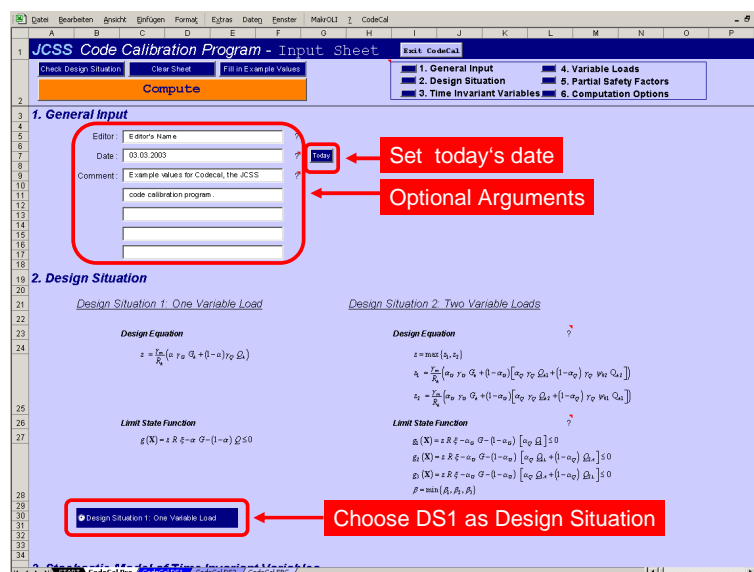


Figure 4. Definition of general input and design situation.

Figure 4 shows where general input can be entered. This comprises the name of the editor, date of analyses and additional comments. The today's date can be set by clicking on a button. These entries are optional. Not optional is the selection of the option button for the design situation, which should be considered. Please, verify that design situation one (DS1) is selected. This design situation considers a permanent load and a variable load. The safety format and notation for the design equation are according to the EUROCODES. Figure 5 shows, where the stochastic models for the time invariant basic variables have to be specified. The distribution type, mean value and standard deviation have to be entered for the resistance the model uncertainty and the permanent/dead load. The quantile of the distribution function, which corresponds to the characteristic value, has to be specified for the resistance and the permanent load. The characteristic value for the model uncertainty is one. On the right side framed by a blue box one can specify additional materials. However, in this example this is not required and entries, which have probably been made are ignored in the computation process.

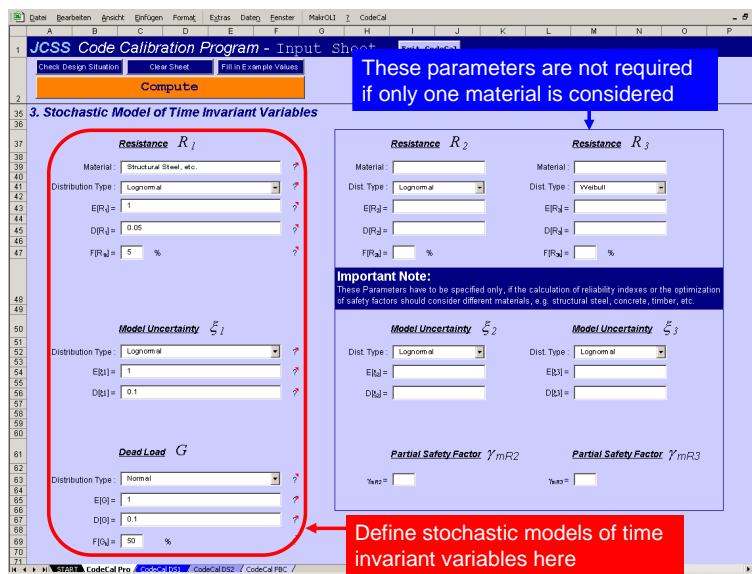


Figure 5. Stochastic models for time invariant basic variables.

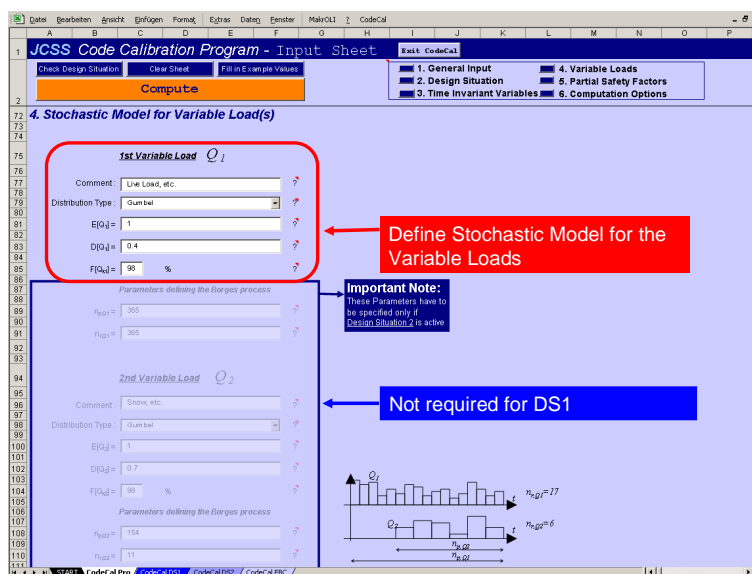


Figure 6. Stochastic model for variable load.

Figure 6 illustrates, where the variable load can be specified. Distribution type, mean value, standard deviation and quantile prescribing the characteristic value are required. A comment is optional. If the example values are used, the basic variables are normalized, such that the mean value is one. In Figure 7 it is seen, where the partial safety factors can be set. Framed by the blue box are the load combination factors. They are not required for this design situation. To evaluate the reliability indexes for a given set of safety factors, please select the option button *Calculate Reliability Index*. Furthermore, as this example considers only one material, *1 Material (R1)* has to be selected.

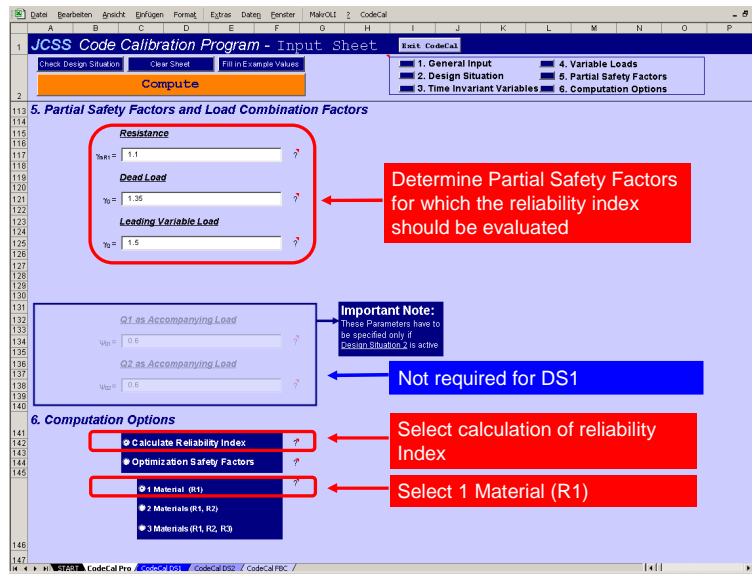


Figure 7. Partial safety factors and computation options.

4.1.3 Output

To start the calculation, press the orange *Compute* button from the CodeCal command bar. The sheet "CodeCal DS1" is activated, which summarizes the input data. Then the reliability indexes are computed. the beta indexes are computed by the FORM. The computed reliability indexes are shown graphically in a diagram and listed in a table.

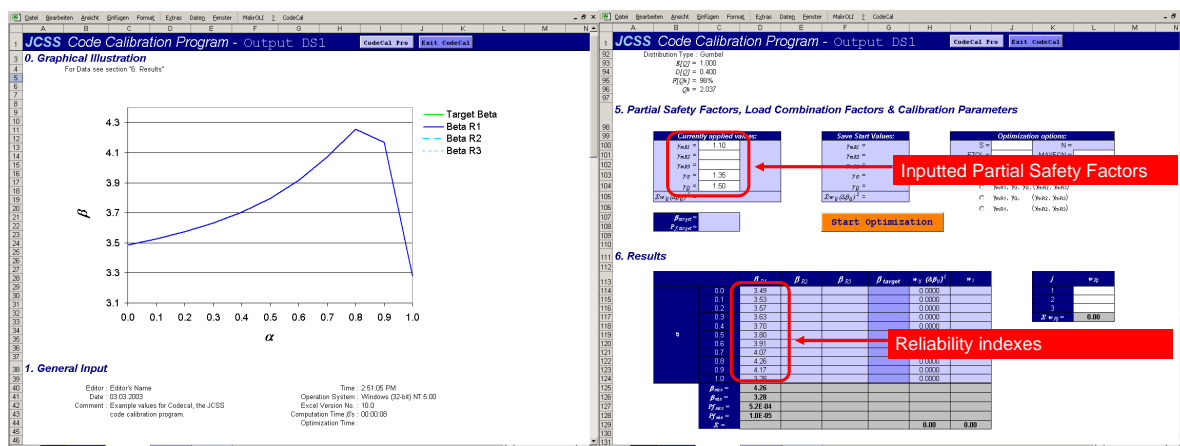


Figure 8. Graphical illustration and table of computed reliability indexes.

4.2 DS1-B-M2/3: Reliability index evaluation for DS1 and two or three materials

4.2.1 Description

This example is based on the foregoing example DS1-B-M1. Therefore, only the differences are described. This example shows the evaluation of reliability indexes for the case, when two or three materials are considered.

4.2.2 Data Input

The same input is required as in the foregoing example DS1-B-M1. Additionally, the stochastic models for the additional materials, the corresponding model uncertainties and partial safety factors have to be specified. This is shown in Figure 9.

The screenshot shows the '3. Stochastic Model of Time Invariant Variables' section of the software interface. It contains three columns of input fields for Resistance R_1 , R_2 , and R_3 . Each column includes fields for Material, Distribution Type, EPR, DPR, and FPR. Below these are sections for Model Uncertainty ξ_i and Partial Safety Factor γ_{mRi} . A red box highlights the R_2 and R_3 sections, with a red text box pointing to it that says: 'Additionally, stochastic models for resistances and associated model uncertainties and Partial Safety Factors have to be specified'.

Figure 9. Required data for additional materials.

The screenshot shows the '5. Partial Safety Factors and Load Combination Factors' and '6. Computation Options' sections. The '5.' section includes input fields for Resistance, Dead Load, and Leading Variable Load. The '6.' section includes radio buttons for 'Calculate Reliability Index' and 'Optimization Safety Factors', and three radio buttons for material selection: '1 Material (R1)', '2 Materials (R1, R2)', and '3 Materials (R1, R2, R3)'. A red box highlights the '3 Materials (R1, R2, R3)' option, with a red text box pointing to it that says: 'Select: 2 Materials (R1, R2) or 3 Materials (R1, R2, R3)'. An 'Important Note' box is also visible, stating: 'These Parameters have to be specified only if Design Situation 2 is active'.

Figure 10. Specification of the number of materials to be considered.

In order to consider two or three materials, select the appropriate option button in the section computation option, see Figure 10.

4.2.3 Output

Figure 11 shows the computed reliability indexes for each specified material. The reliability index is plotted as a graph and listed in a table.

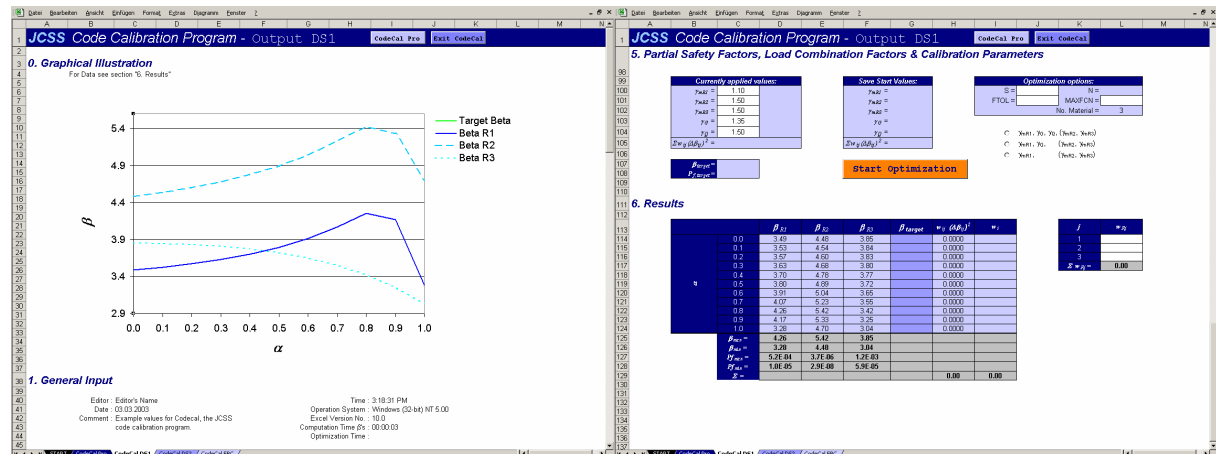


Figure 11. Graphical illustration and table of calculated reliability indexes for each material.

4.3 DS1-O-M1/2/3: Optimization of safety factors for DS1

4.3.1 Description

This example illustrates the optimization of partial safety factors. Within this example, design situation one (DS1) is considered. Depending on the selected number of material, which should be considered, one, two or three materials are accounted during the optimization process.

4.3.2 Data Input

The same input is requires as in the foregoing examples. Therefore, only the differences are described. In order to optimize the partial safety factors different computation options have to be specified. Figure 12 shows that first of all, the option button *Optimization Safety Factors* has to be selected. Secondly, the number of materials, which should be considered within the optimization, has to be selected. Then the target reliability level has to be entered and the set of safety factors, which should be optimized, has to be specified, as well. Further more, weights can be entered for different materials and for different values of α_G . α_G is the ratio of permanent to total load (permanent plus variable load). Finally, computation options for the optimization routine can be determined.

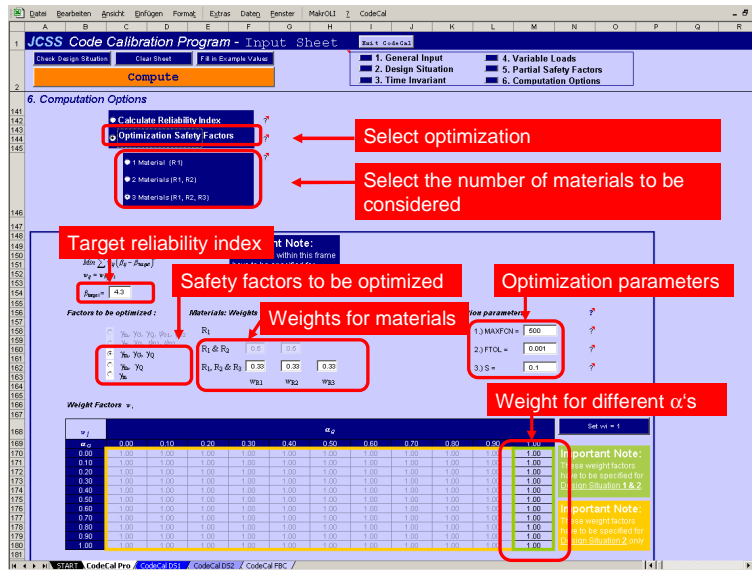


Figure 12. Computation options for optimization.

4.3.3 Output

Press the *Compute* button to start the computation. Firstly, the sheet *CodeCal DS* is activated and the reliability indexes are evaluated for the start values of the safety factors. To start the final optimization, press the *Start Optimization* button. Figure 13 shows three curves. Each of them represents the reliability index for a specified material. It shows that the curves are closer to the target reliability level than seen in Figure 11. On the right hand side of Figure 13 tables are given with computed reliability indexes and optimized partial safety factors.

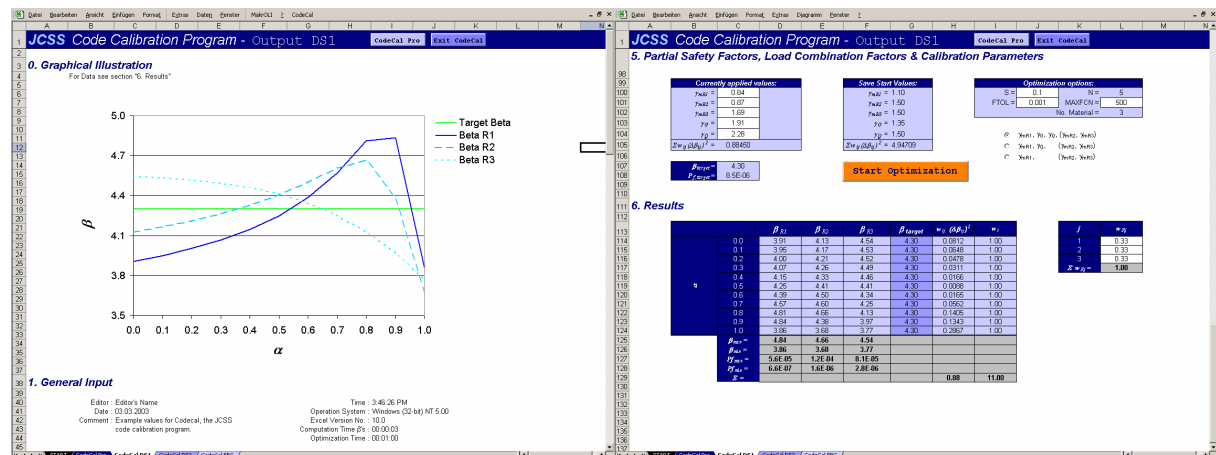


Figure 13. Graphical illustration for three materials and the calculated beta values.

4.4 DS2-B-M1/2/3: Reliability index calculation for DS2 and one, two or three materials

4.4.1 Description

This example evaluates the reliability indexes for design situation 2 (DS2). It considers a permanent and two variable loads acting on a structure. Depending on the selected number of material, which have to be considered, the reliability indexes may be evaluated for one, two or three materials.

4.4.2 Data Input

Most required entries have to be inputted like already shown in the foregoing examples. Therefore, only the differences are described within this example. Firstly, design situation two (DS2) has to be selected, as seen in Figure 14. Further more, the second variable load has to be specified. Additionally, the parameters, which allow describing the variable loads as Borges processes, have to be specified. This allows considering load combination by means of the Ferry Borges-Castanheta load combination model. In addition to the partial safety factors, the load combination factors have to be specified, as well.

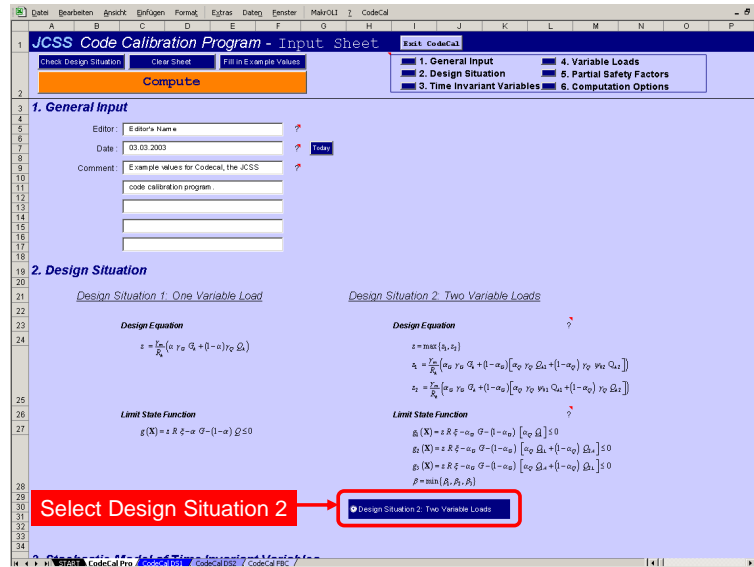


Figure 14. Design situation two (DS2).

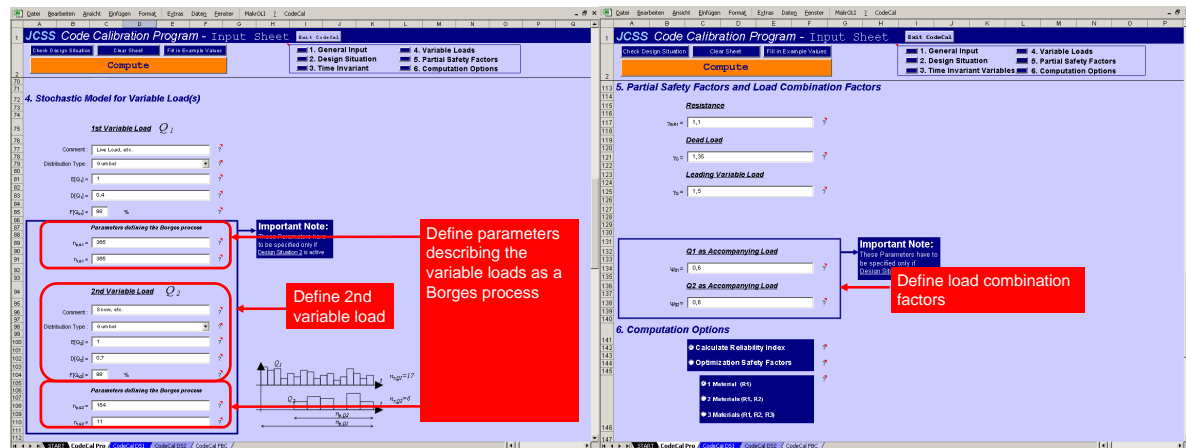


Figure 15. Variable loads and load combination factors.

4.4.3 Output

The sheet *CodeCal DS2* summarizes the entries and the computed reliability indexes. For each material the computed reliability indexes are summarized in a matrix. The corresponding diagram shows a 3D – surface.

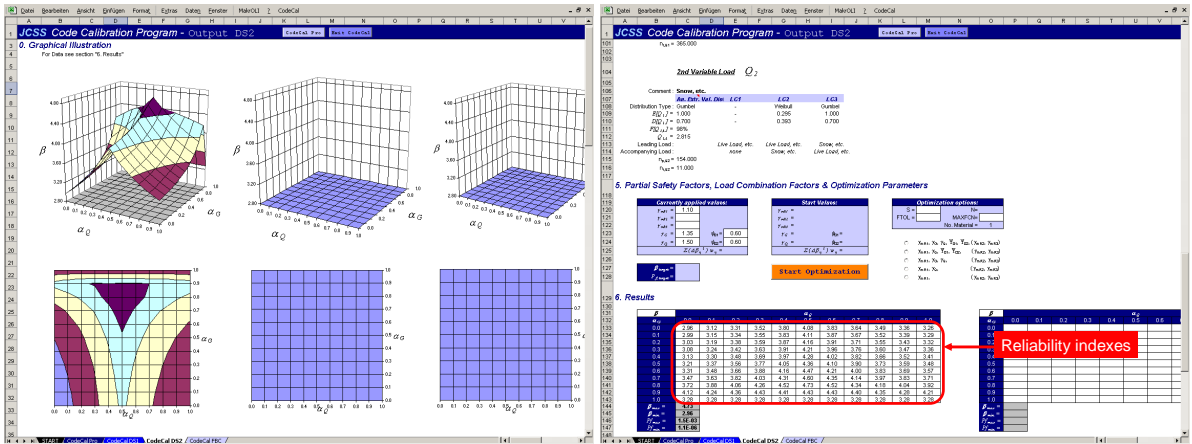


Figure 16. Calculated reliability indexes for DS2 and one material.

4.5 DS2-O-M1/2/3: Optimization of safety factors for DS2

4.5.1 Description

This example illustrates the optimization of optimize partial safety and load combination factors. Within this example, design situation two (DS2) is considered. Depending on the selected number of materials, which should be considered, one, two or three materials are accounted during the optimization process.

4.5.2 Data Input

This example is based on the foregoing example. Therefore, only the additional input is described. In order to optimize the partial safety factors different computation options have to be specified. Figure 17 shows that the option button *Optimization Safety Factors* has to be selected. Secondly, the number of materials, which should be considered within the optimization, has to be selected, as well. Then the target reliability level has to be entered and the set of safety factors, which should be optimized, has to be specified. Further more, weights can be entered for different materials and for different α 's. Finally, computation options for the optimization routine can be determined.

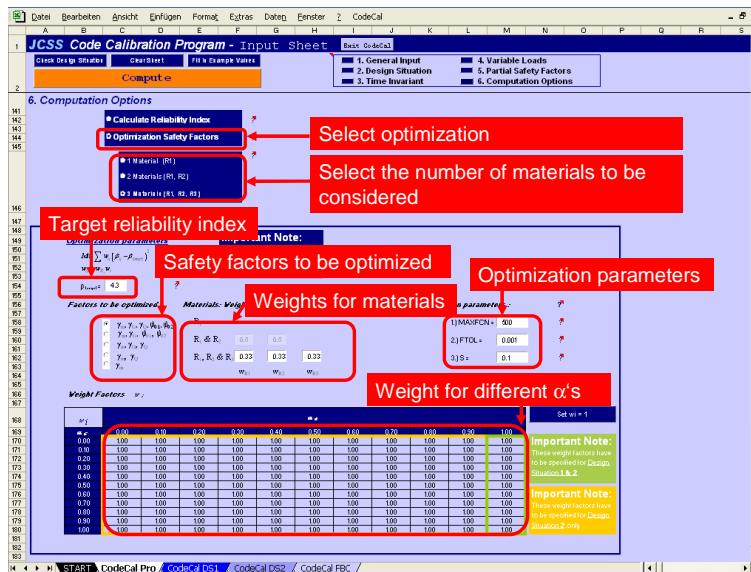


Figure 17. Computation option for optimization.

4.5.3 Output

After pressing the *Compute* button the sheet *CodeCal DS2* is activated and the reliability indexes are evaluated for the start values of the safety factors. To start the optimization, press the *Start Optimization* button. Figure 18 shows three 3D – surfaces. Each of them represents the reliability index for a specified material and design situation two. On the right hand side of Figure 18, tables show the computed reliability indexes and optimized partial safety factors.

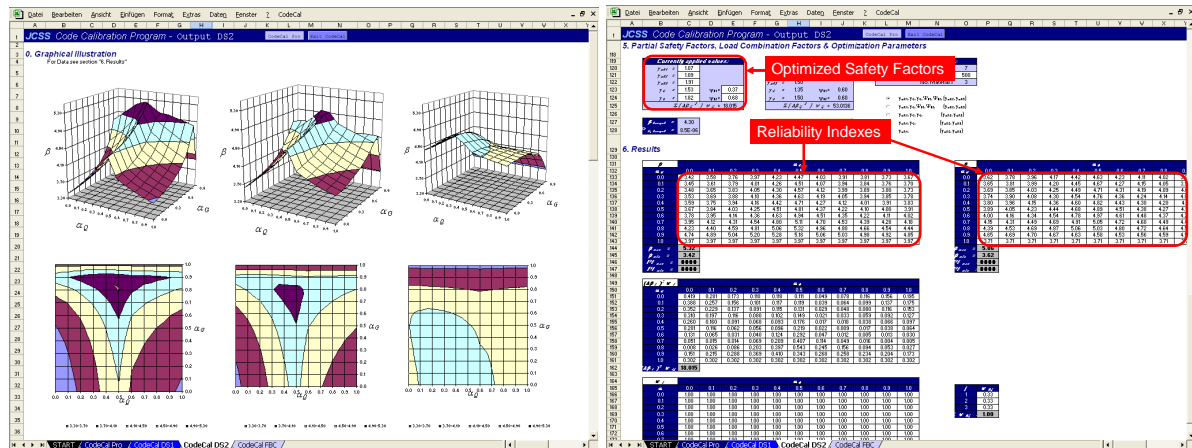


Figure 18. Reliability indexes for three materials for optimized safety factors.

5 References

Faber, M.H. & Sørensen, J.D. 2003. "Reliability Based Code Calibration - The JCSS Approach". *Proceedings of the 9th International Conference on Applications of statistics and Probability*. San Francisco.

EUROCODE 1. 1993. *ENV 1991-1. Basis of design and actions on structures*.