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ConcreteDesigner Bridge

ConcreteDesigner Bridge designs reinforcement for concrete beams, with given section forces, according to EN 1992-1-1:2004 and national annexes. The program generates a report which includes both graphical and numerical results. The user can easily create a complete report to simplify the presentation to the client.

User manual

Rev: F

Eurocode Software AB

1 General

After choosing result lines from BRIGADE the user can start the program *ConcreteDesigner Bridge*. The program calculates the required amount of reinforcement in ultimate and serviceability limit state and checks fatigue. It is also possible to let the program find the envelope of the needed reinforcement along an optional number of result lines.

Operations

- Moment charts for the chosen lines
- Reduction of section forces over supports
- Calculation of necessary reinforcement with regard to ultimate and serviceability limit state
- Average of necessary reinforcement for a number of lines
- Display of arrangement of transverse reinforcement
- Automatic calculation and distribution of bending reinforcement in ultimate and serviceability limit state
- Check of fatigue of longitudinal (bending) reinforcement
- Choose which/how many sections will be presented in the numerical report

The report includes:

- Moment graphs
    - ULS, max/min moment graph
    - SLS, max/min moment graph
- Necessary amount of reinforcement
    - ULS, bending and shear
    - SLS
- Amount of used reinforcement
    - Rebars for bending and shear
- Fatigue
    - Bending
    - Shear
- Reinforcement sketch
    - Reinforcement sketch in dxf-format

Geometry, sectional forces and results are presented graphically. The charts show all sections from BRIGADE.

This user manual describes the program by showing the methods used for calculations and a step by step guide on how to use the program. The manual also covers all operations in the program, based on where you find them in the menu.

1.1 Denotations

Ec2	EN 1992-1: 2004, design of concrete structures
ULS	Ultimate limit state
SLS	Serviceability limit state
E	Load effect
Ed	Design value of load effect
R	Resistance
Rd	Design value of resistance

1.2 Method

The method used to design the reinforcement in a strip is described below.

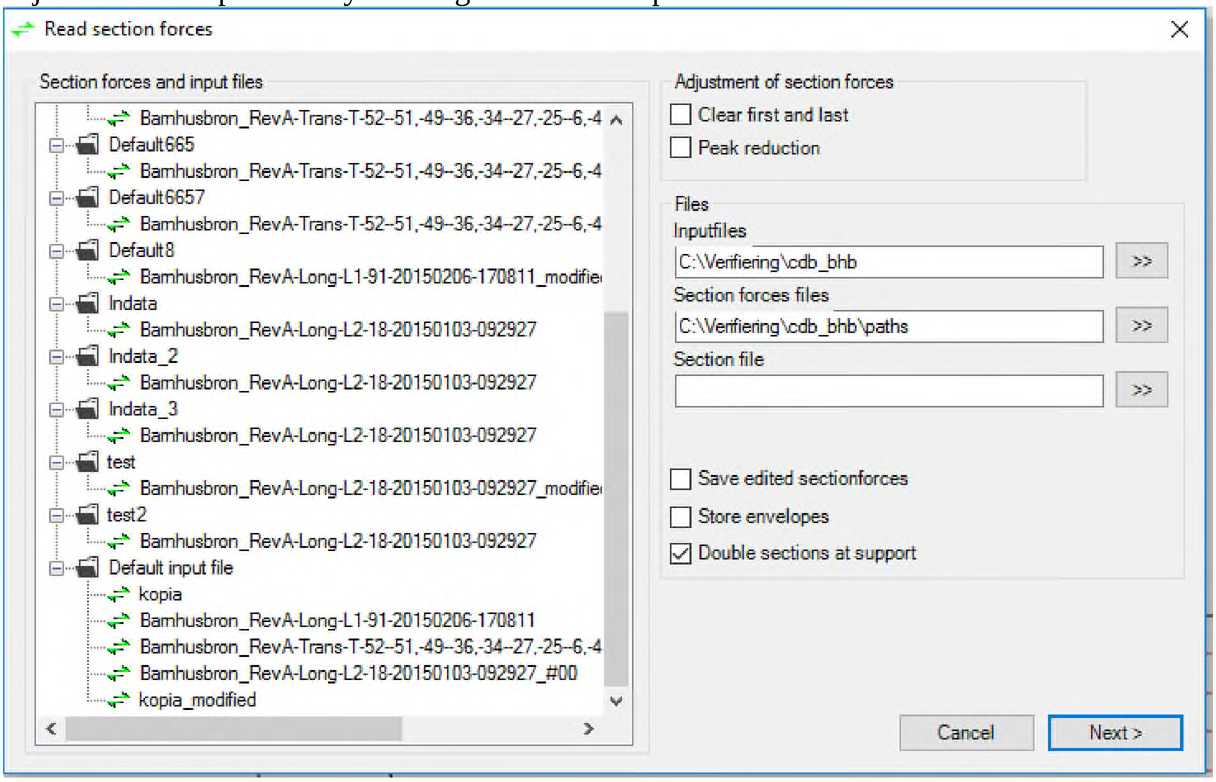
Design of a region/strip

- One or many result lines, longitudinal or transversal, are chosen for the region where section forces shall be calculated. This is done in BRIGADE.
- BRIGADE finds the design section forces of the reinforcement for the chosen result lines. The section forces are calculated either along or transverse the lines depending on the type of reinforcement is to be designed.
- BRIGADE creates a file containing the following information:
    - Coordinates and node numbers
    - Section geometry
    - Design section forces
- *ConcreteDesigner Bridge* reads the file and does the following:
    - Calculates the maximum load effect for every section of each line sends several max/min-values for the same point depending on how many load combinations have been chosen for the current result line.
    - Designs the reinforcement in ultimate and serviceability limit state for each result line.
    - Determines the amount of reinforcement needed with regard to fatigue.
- For each section, you may choose which type of graphs will be shown.
    - Single: *ConcreteDesigner Bridge* displays necessary reinforcement amount and utilization rate for each line
    - Average: *Concrete Design Bridge* displays the average values for multiple result lines.
    - Max/min: *Concrete Design Bridge* splays the max/min-values for multiple result lines.

1.3 Step by step guide to ConcreteDesigner Bridge

1. In BRIGADE, choose result lines in the region where you want to calculate the sectional forces, and perform the calculation. When the calculation is done you will be sent to *ConcreteDesigner Bridge* automatically. If you have done calculations with the same input data before, i.e. the same material, parameters and so on, but with different result lines, you can either choose to use the guide or proceed to chapter 1.4.4.

2. You are sent directly to the dialogue *Read section forces.* Do the necessary adjustments and proceed by clicking *Next.* See chapter 5.6 for more information.



1.4 Input files

Input data files are created by BRIGADE and can thereafter be used by ConcreteDesigner Bridge

1.4.1 [Section_forces].xml

Such a file is created every time you run BRIGADE. The file is created automatically and stored in the bdb-catalogue and contains sectional forces and geometry.

1.4.2 [Input_file].xml

This file is created every time you save a file in *ConcreteDesigner Bridge.*

This file contains material data for concrete and reinforcement steel, as well as arrangement of bending and shear reinforcement.

In this file there is a connection to the corresponding [Section_forces].xml.

1.4.3 Handling and editing of files

1.4.3.1 Connection between [Section_forces].xml and [Input_file].xml

- For each combination of lines run in BRIGADE the file [Section_forces].xml is created.
- [Input_file].xml is created when you save your work in *ConcreteDesigner Bridge* for the first time. The file should be saved in the appropriate catalogue (for example the bdb-catalogue).
  Alternatively you can move all files regarding the design ([Section_forces].xml and [Input_file].xml) to a separate folder. In this case the connection between the two files must be edited in [Input_file].xml. This also applies if you change the name of the [Section_forces].xml file.
- Edit the connection by opening [Input_file].xml in Notepad, or a similar program, and change the path in:
  <File>
  <name>[Section_forces].xml </name>
  </File>
  As long as the files are placed in the same folder it is enough to refer to the name of the file, otherwise the entire path is needed.

1.4.3.2 Modification of input for each part

- Start the program brdEc210 (ConcreteDesigner Bridge).
- Open the input file [Input_file].xml.
  The program reads the section forces and geometry from [Section_forces].xml and other input from [Input_file].xml.
- Make your adjustments and save the input file [Input_file].xml with its modifications. You cannot save changes in geometry here, since the geometry is read from the file [Section_forces].xml.

1.4.4 Use an existing input file

If you want to do multiple calculations in one project, with the same input but with different result lines and section forces, you can use the first input file you made, [Input_file].xml, as a template.

- Create a copy of the input file you want to use, [Input_file_copy].xml.
- Run a calculation to find sectional forces in BRIGADE. When *ConcreteDesigner Bridge* is opened just close it.
- Move the new file [Section_forces].xml to the folder where [Input_file_copy].xml is saved. Then change the connection between the files, see chapter 1.4.3.1, so that [Input_file_copy].xml directs to the new file with section forces.

Open *ConcreteDesigner Bridge* and open [Input_file_copy].xml. The file now has the exact same settings as [Input_file].xml and you may proceed directly to the reinforcement arrangement see chapter 6.1.2.1.

2 Basics

The function of the buttons in the start window is described here. The remaining functions are described in the following chapters.

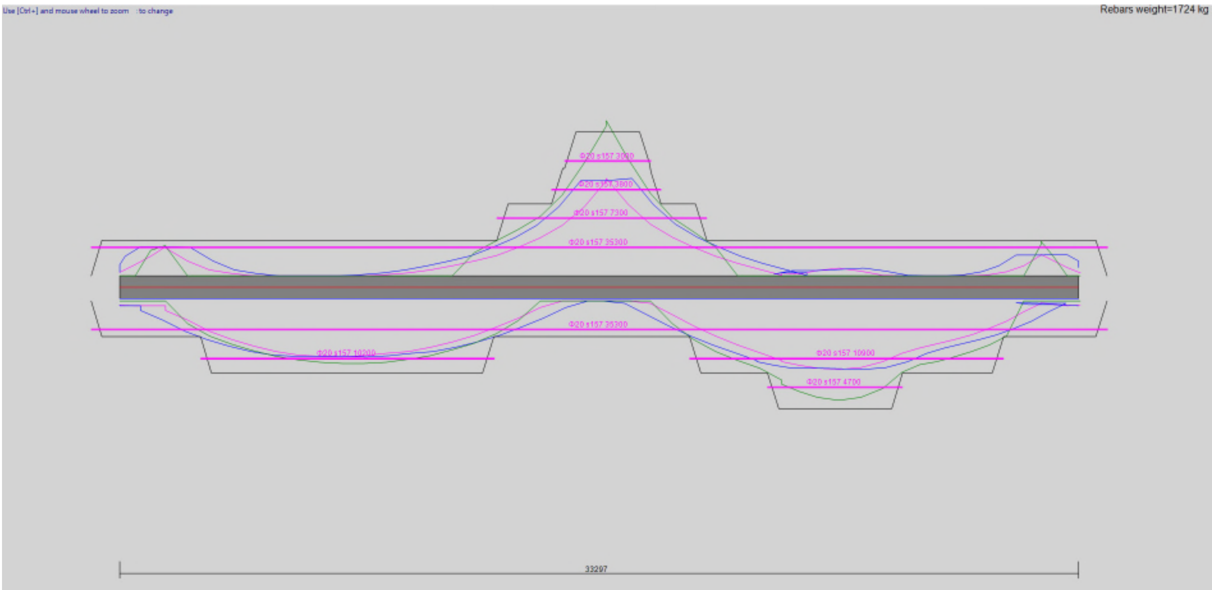
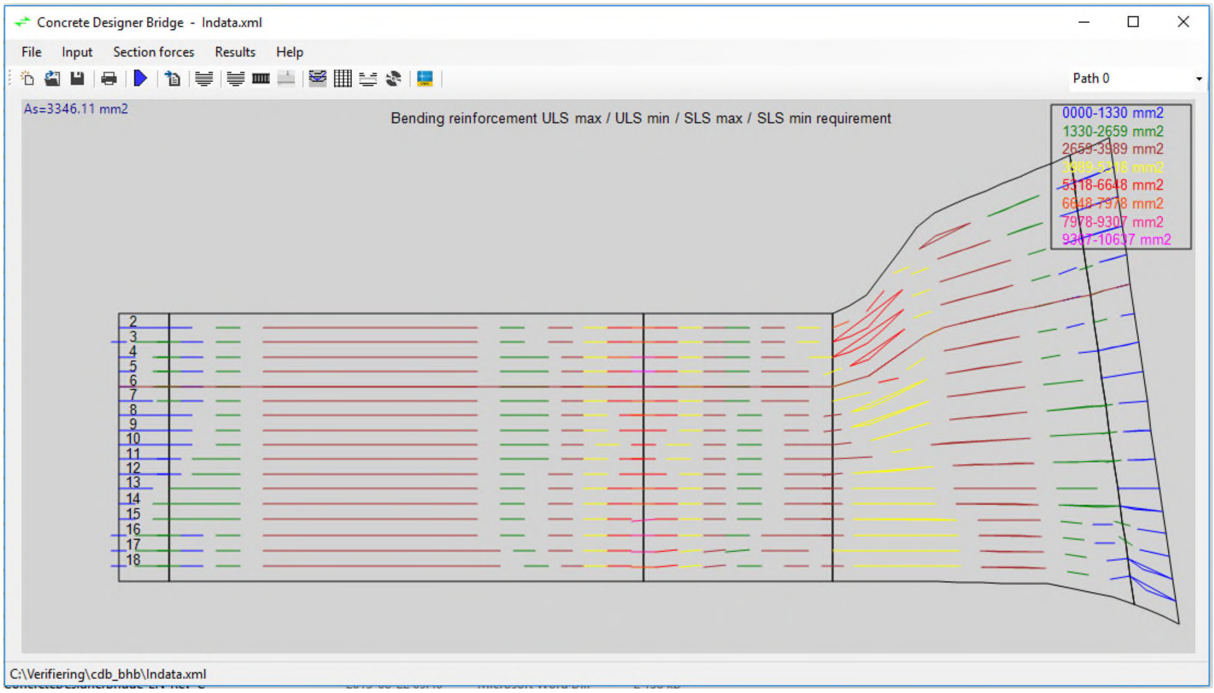
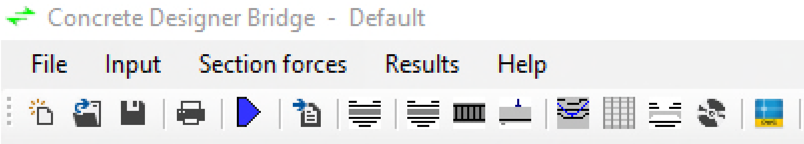


Figure 1 Start elevation

If you have exported both section forces and geometric data the reinforcement amount for bending or shear forces are plotted. Each line describes the amount of reinforcement along the Brigade result line.



2.1 Buttons



New

Open input file

Save input file

Print

Guide

Read section forces see 5.6

Generate rebar location

Arrange rebars, see 6.1.2

Arrange strirups, see 6.2.2

Shear dim parameters see 2.1.1

Reinforcement paths see 2.1.2

Graphics plane see 2.1.3

Graphics elevation see 2.1.4

Force recalculation, the program makes a recalculation

Reinforcement sketch 2.1.5.

2.1.1 Shear dim parameters

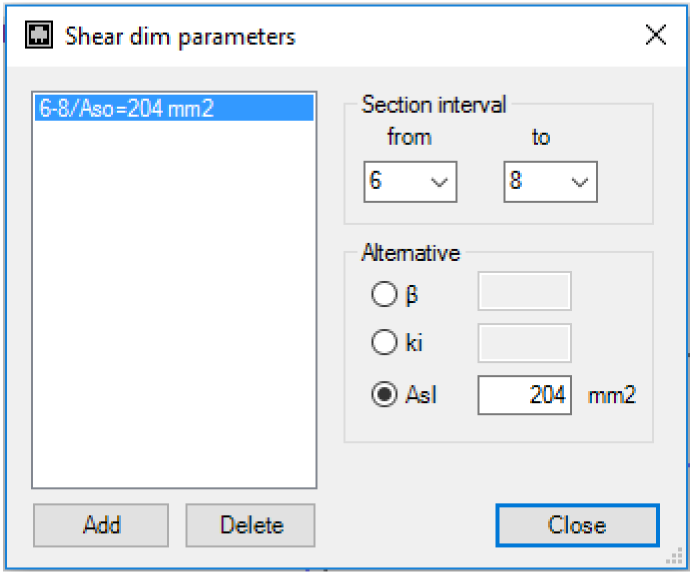
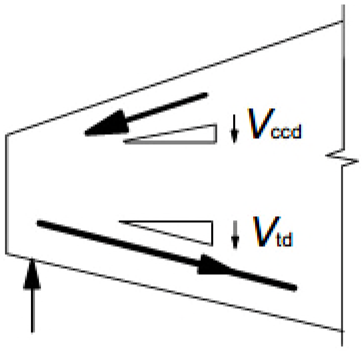


Figure 2 Shear dim parameters

β Ec2 6.32.3(8) for members with loads applied on the upper side within a distance $0{,}5d \leq a_v \leq 2{,}0d$ the contribution of this load to the shear foce V_{Ed}may be reduced by$\beta = a_v/2d$.

k_i Ec2 6.2.1 (1) for members with inclined chords for the calculation of V_{ccd} andV_{td}. , where Vi=ki*M_{Ed}/d



A_{sl} Given amount of reinforcement, used when calculation the shear resistance accordingly to Ec2 6.2.2. eq (6.2.b)

2.1.2 Reinforcement paths

The user divided the bridge into appropriate number of path the reinforcement amount and arrangement is constant.

The program curtailment the reinforcement according to the specified module. As an alternative the user can manually curtail the reinforcement. The module defines the levels for reinforcing curtailment.

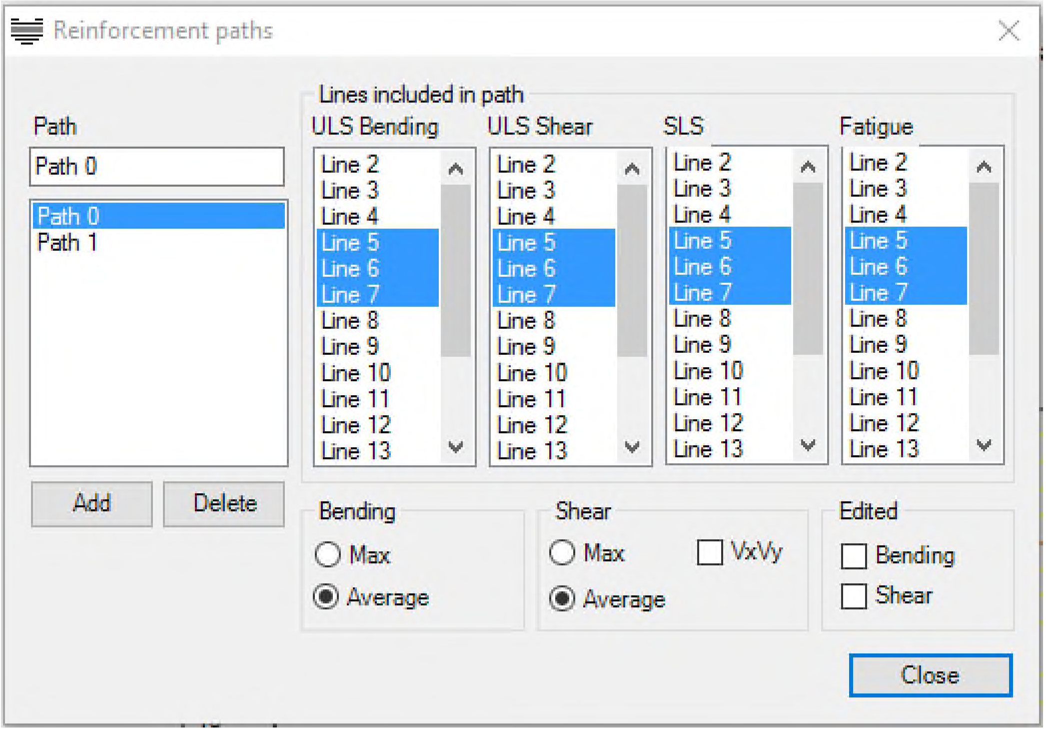


Figure 3 Reinforcement paths

Path	A list of numbers of path, each path is including number of lines
	Adding new path, you can also rename the “path 0” to your own need. To highlight more lines into the list, use *Ctrl+Mouse pointer*.
	Delete path, choose one the path# that you don’t need
ULS bending	Decide which line will show in ULS bending reaction
ULS shear	Decide which line will show in ULS shear reaction
SLS	Decide which line will show in SLS reaction
Fatigue	Decide which line will show in fatigue.
Bending Max	maximum reinforcement amount for the path is calculated
Bending average	average reinforcement amount for the path is calculated
Shear Max	maximum reinforcement amount for the path is calculated
Shear average	average reinforcement amount for the path is calculated
Shear Vx/Vy	the shear reinforcement is calculated for $\sqrt{V_x^2 + V_y^2}$

Edited bending if the box is marked means the user has manually curtail the bending reinforcement, if the box unmark then the program curtailment the reinforcement. For editing the reinforcement in bending see detailing bars 6.1.2.

Edited shear if the box is marked means the user has manually curtail the shear reinforcement, if the box unmark then the program curtailment the reinforcement. For editing the reinforcement in shear see. Arrange stirrup 6.2.2.

2.1.3 Graphics plane

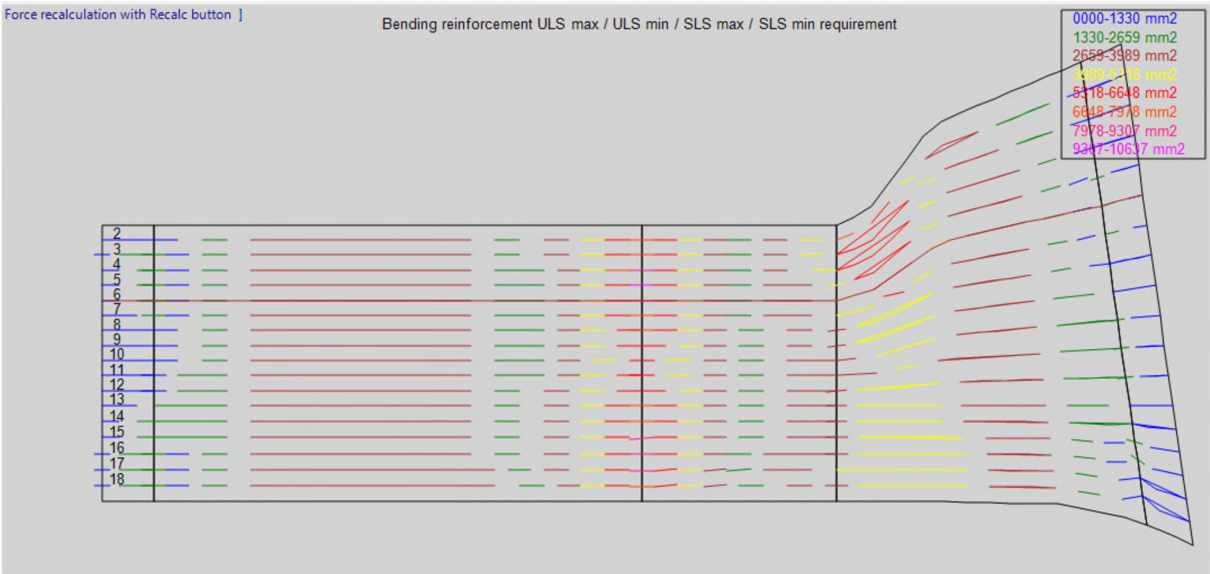


Figure 4 Graphics plan in xy direction

Brown line Centre of current path

Black line Parts of the bridge deck

Other colors Amount of reinforcement accordingly to the legend

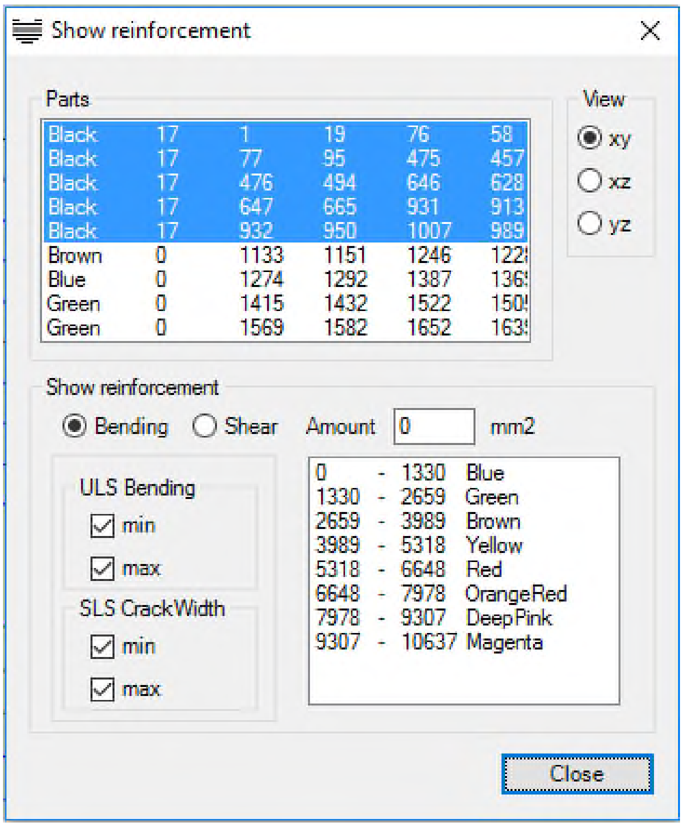


Figure 5 Show reinforcement

To open this dialog you will have to “right click” in *Graphics plan* mode. You are able to change different view of the bridge and different type amount of reinforcement react.

Parts	part of the deck, numbering comes from BRIGADE
View xy	view the geometry and reinforcement in the xy-plan
View xz	view the xz-plan
View yz	view the yz-plan
Show reinforcement	
Bending	show bending reinforcement
Shear	show shear reinforcement
Amount	Amount of dividing the reinforcement in steps. For “0” means the program will generate automatically.
ULS bending min	show reinforcement for the min section forces
ULS bending max	show reinforcement for the max section forces
SLS shear min	show reinforcement for the min section forces
SLS shear max	show reinforcement for the min section forces

2.1.4 Graphics elevation

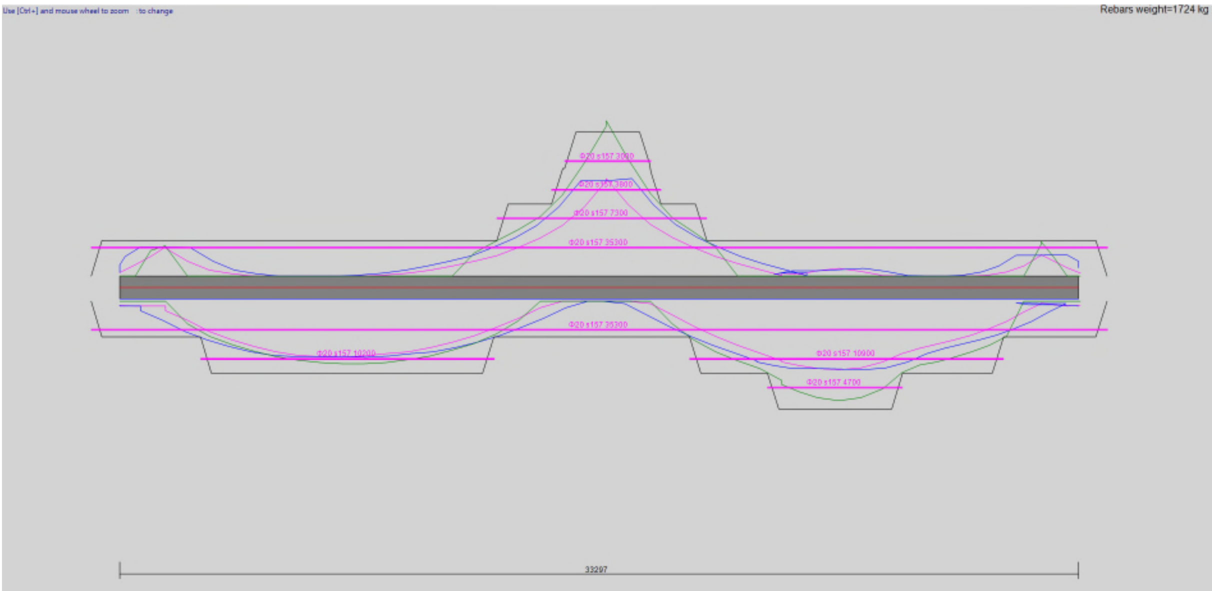


Figure 6 Graphics elevation

A view of elevation of the bridge. The elevation is included the amount of reinforcement in bending and shear and the diagrams.

2.1.5 Reinforcement sketch

The reinforcement sketch is written to a file in dxf format, then the program starts the default program for dxf-files.

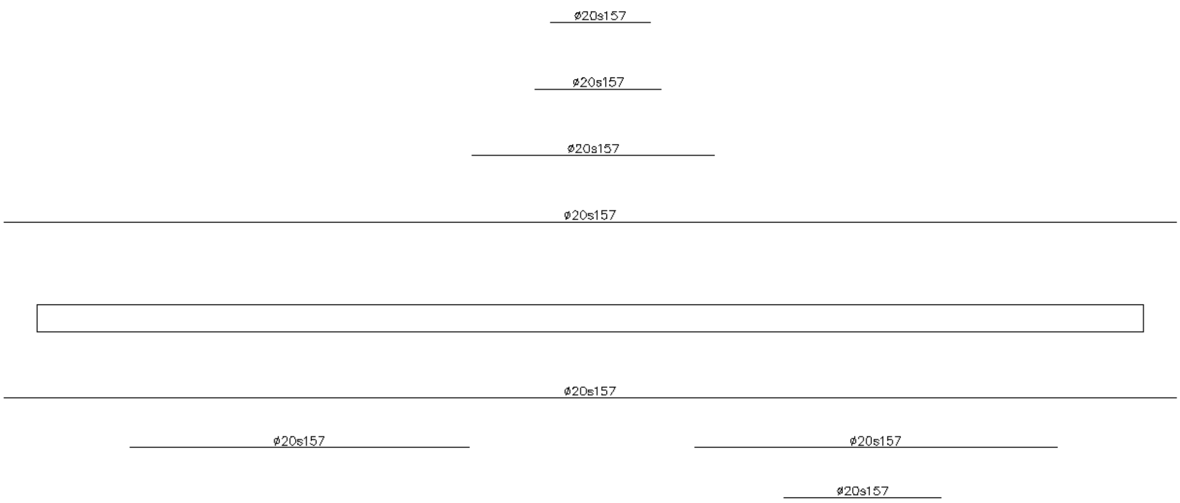


Figure 7 Reinforcement sketch in dwg-file

3 File

Under *File* you can find the tools; *New, Open, information, Save, Save as and Exit.*

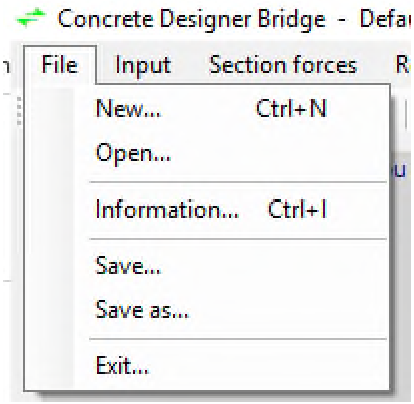


Figure 8 File

3.1 Project description

At *Information* it is possible to state which project it is, the location of the member, which appendix it is and a short description. This information will be printed in the report.

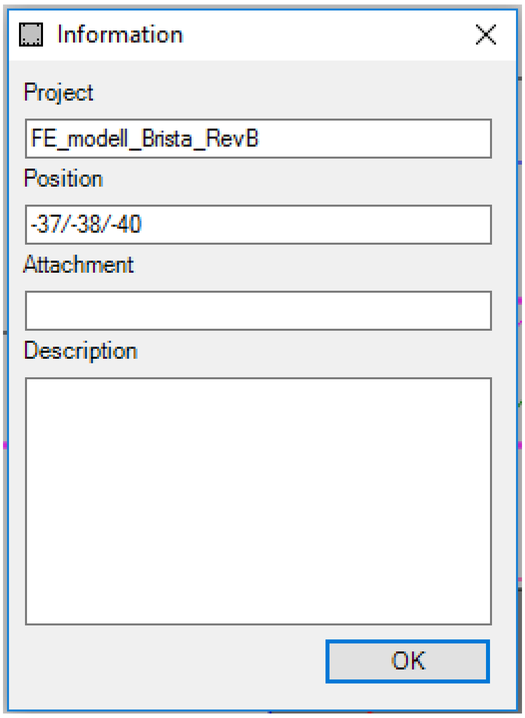


Figure 9 Project description

4 Input

Under the tab *Input* you find settings for material properties, geometry and other parameters.

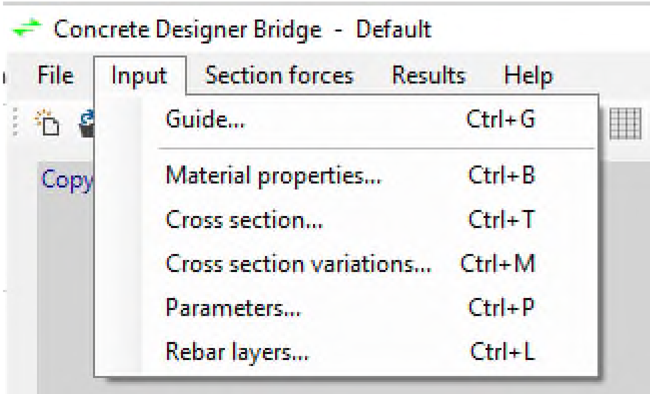


Figure 10 Input data

4.1 Material properties

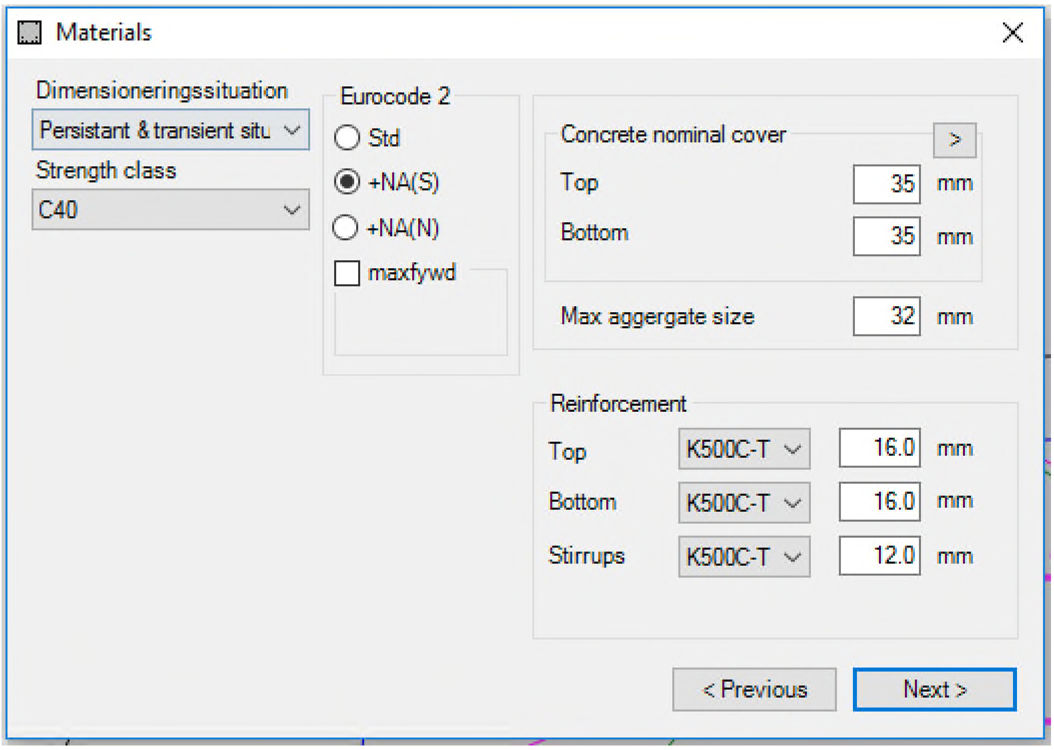
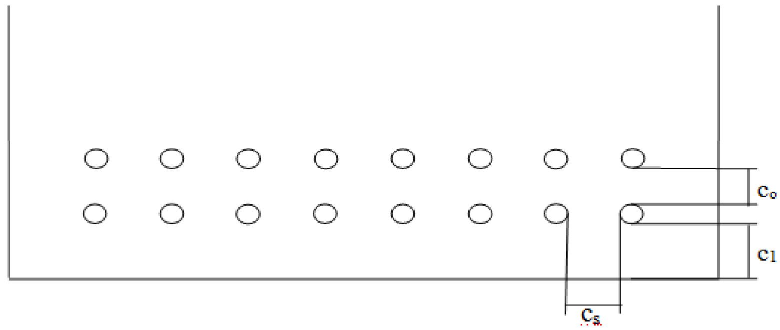


Figure 11 Material properties

Partial factors for material

Concrete property	the user sets a concrete class according to Ec2, table 3.1. It is also possible to set a concrete class which is not predefined.
Std, +NA(S), +NA(N),	A couple of different national settings can be used in the design. In this version the user can choose between the following: Std Standard Eurocode

	+NA(S)	EKS – Swedish national annex
	+NA(N)	Norwegian national annex
max fywd	Designing the shear reinforcement the user can choose maximum yield stress for the reinforcement.	
Concrete nominal cover	the program considers other parameters needed to calculate a sufficient concrete cover and minimum distance between longitudinal reinforcement. Stirrups are regarded when calculating concrete cover for beams.	



Maximum aggregate size Used when calculating the free distance between reinforcement bars in and between layers.

Reinforcement Set type and diameter of reinforcement.

The button: > Environment: For environment dependent settings such as structural class and exposure class

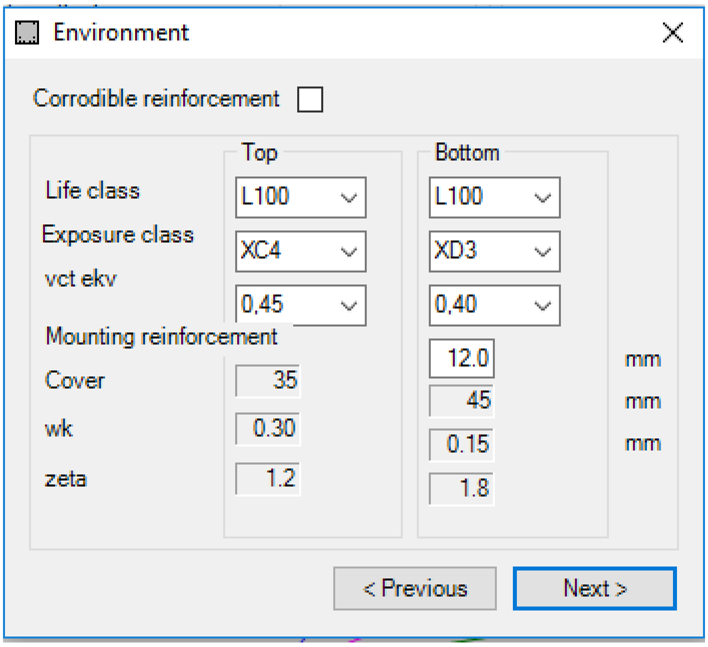


Figure 12 Environment

4.2 Cross section

If an input file from Brigade is used the geometry of the cross section will be imported automatically. Otherwise, this dialogue is used for constant cross-sections, if the cross-section varies insert data according to chapter 4.3.

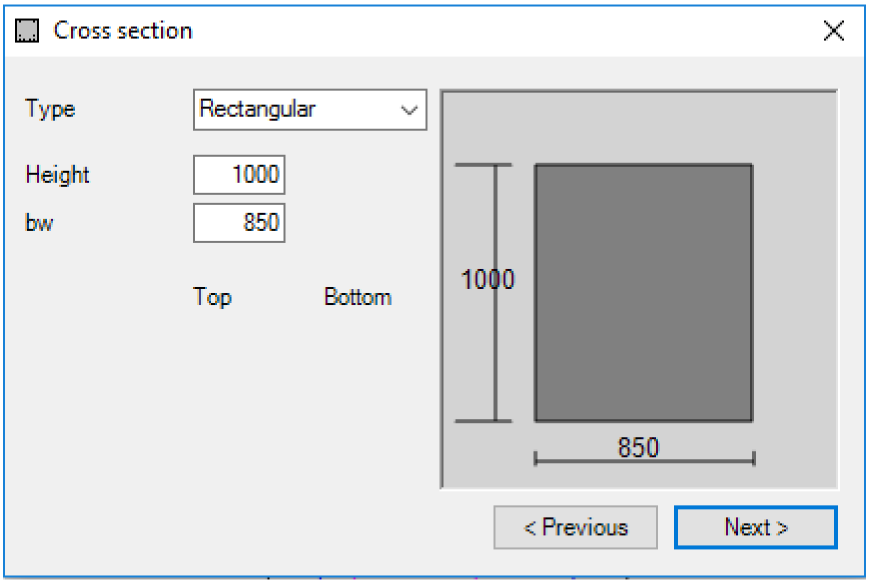
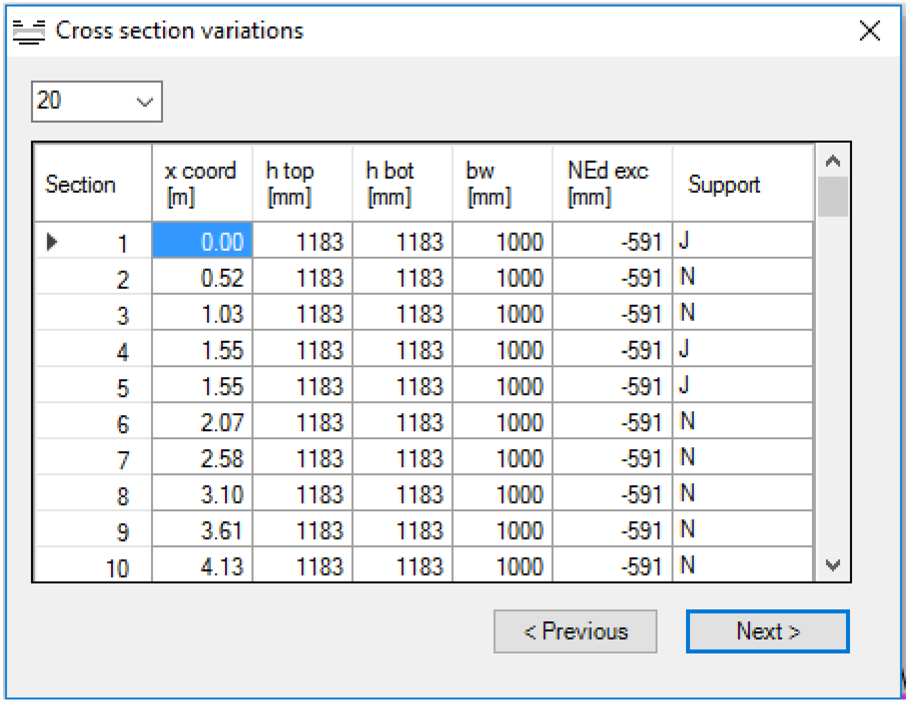


Figure 13 Cross section

Type	Type of cross-section chosen as one of the following, this choice governs which input data is to be given: 1=rectangular 2=T-section 3=L-section 4=_|_-section 5=O-section 6=I-section 7=slab strip bw=1000 8=Through shaped section 9=Special beam 10=I-section delta bf
height	Total height of the beam
bw	Width of the web
bf	Total width of the flange (including web width), if there is no flange set b=0.
tf	Flange thickness, if there is no flange set t=0.
ts	Inclined length

4.3 Cross section variations

Used for varying cross-sections. Input is imported automatically from Brigade but can be changed.



Section	x coord [m]	h top [mm]	h bot [mm]	bw [mm]	NEd exc [mm]	Support
1	0.00	1183	1183	1000	-591	J
2	0.52	1183	1183	1000	-591	N
3	1.03	1183	1183	1000	-591	N
4	1.55	1183	1183	1000	-591	J
5	1.55	1183	1183	1000	-591	J
6	2.07	1183	1183	1000	-591	N
7	2.58	1183	1183	1000	-591	N
8	3.10	1183	1183	1000	-591	N
9	3.61	1183	1183	1000	-591	N
10	4.13	1183	1183	1000	-591	N

Figure 14 Varaiation of cross section

Xkrd	x-coordinates, from left to right
h, top	Total height of the beam, used to design top reinforcement.
h, bot	Total height of the beam, used to design bottom reinforcement. Useful for design of reinforcement in haunched slabs
bw	Web width
Nexc	Eccentricity of axial force, given from the top of the section positive upwards. Usually equal to –h/2.
Support	J- Support in the section N- No support in the section Used to identify supports for moment reduction over supports.

4.4 Parameters

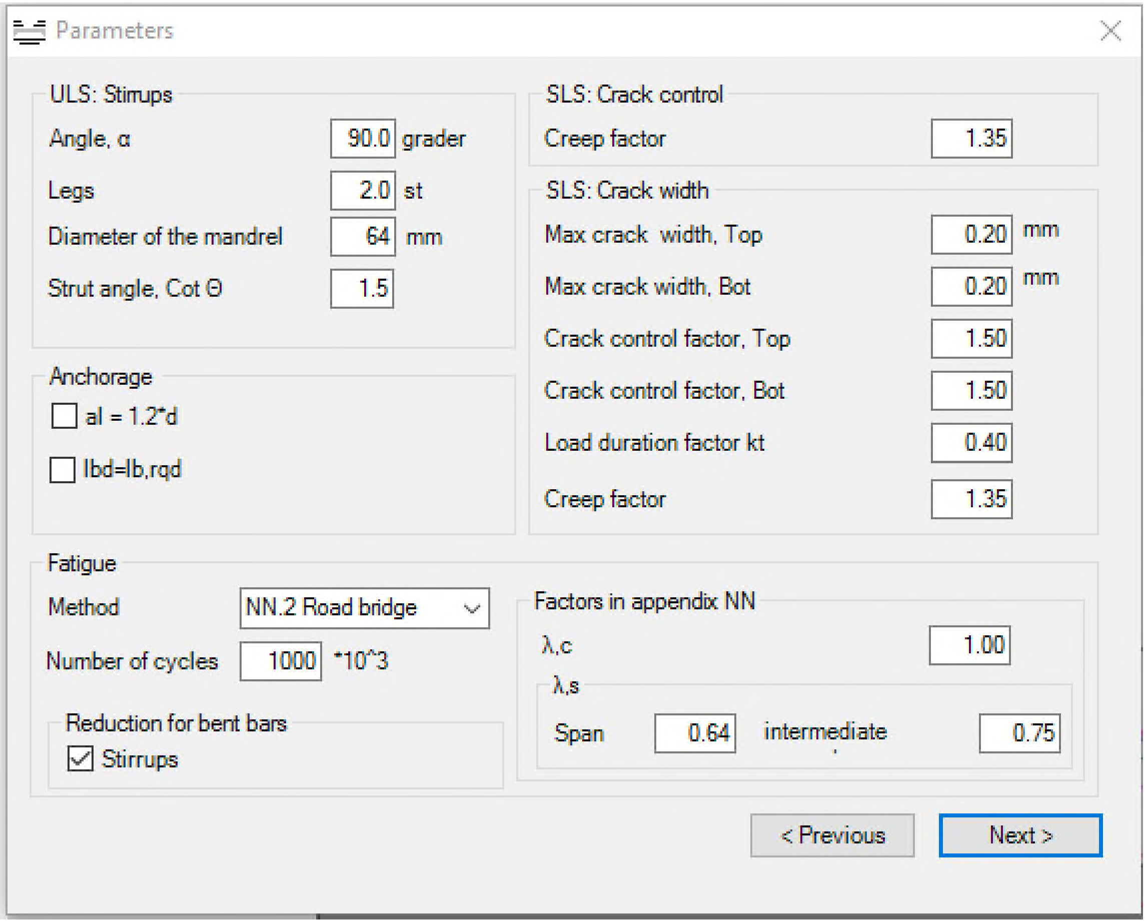


Figure 15 Parameters

ULS: Stirrups:

Alpha,α	Angle of the stirrups, in the dialogue for reinforcement arrangement the user can define different stirrup angles for different parts of the beam.
Legs	Number of legs for stirrups.
Diameter of the mandrel	Bending diameter for shear reinforcement, used in fatigue control

Anchorage length:

al	Shift of the tensile force graph is set to 1,2*d, alternatively calculated according to Ec2.
lbd	Check this box to set anchoring length to the basic value.

Fatigue

Choose a method for fatigue calculations:

Method:	NN.2 Road bridge
	NN.3 Railway bridge

	Palmgren-Miner rule
Number of cycles	Number of cycles, to find an appropriate number use chapter 4.5.1 if Palmgren-Miner rule is used
Reduction for bent bars, stirrups	Check if there are bent bars or stirrups
SLS: Crack width:	
Maximum allowable crack widths	
Top	Maximum allowed crack width on top of the section.
Bot	Maximum allowed crack width on the bottom of the section.
Crack control factor, Top	Safety factor for cracking, ζ, at the top of the section, used when calculating $f_{ct,fl}=k \cdot f_{ctm}/\zeta$. If ζ is set to zero the following equations will be used to find if the section is cracked: $f_{ct,eff}=f_{ctm},$ $\sigma_c<f_{ct,eff}$, pure bending $\sigma_{cn}+\sigma_{cm}<f_{ct,eff}$,bending and axial forces
Crack control factor, Bot	Safety factor for cracking, ζ, at the bottom of the section.See above.
Factor kt	Factor considering the duration of load, 0,4 or 0,6.
Creep factor	Final creep ratio, Ecd,eff=Ecd/(1+φ_{eff}).
Factors in Appendix NN	Settings under *Factors in Appendix NN* depends on the type of bridge, railway or road. If it's a road bridge a correctional factor for steel, λ_s, and one for concrete, λ_c, is set. For a railway bridge the correctional factor should also be multiplied by a dynamical factor, φ. If you chose to use Palmgren-Miner rule his section is not used.
Road Bridge	
Lambda, λ_c	damage equivalent factor for concrete, see Ec2 Appendix NN equ. NN.101
Lambda, λ_s	damage equivalent factor for fatigue, steel, see Ec2 Appendix NN equ. NN.101
Rail Bridge	
Lambda, c*fi	damage equivalent factor for steel, λ, multiplied by a dynamical factor, φ. See Ec2 Appendix NN equ. NN.106.
Lambda, s*fi	damage equivalent factor for concrete, λ, multiplied by a dynamical factor, φ. See Ec2 Appendix NN equ. NN.106.

4.4.1 Find number of cycles for using Palmgren-Miner rule

Palmgren-Miner is founded on finding the fatigue damage factor, D_{Ed}, for the steel. This factor is the sum of the number of loading cycles during the life of the structure divided by the resisting number of load cycles during the same time. Thus, the condition is that D_{Ed} should be less than one.

$$D_{Ed} = \sum_i \frac{n(\Delta\sigma_i)}{N(\Delta\sigma_i)} < 1 \qquad \text{Ec2 6.8.4(2), equation 6.70}$$

where $n(\Delta\sigma_i)$ is the applied number of cycles for the stress range
$N(\Delta\sigma_i)$ is the resisting number of cycles for the stress range

N is given by the Wöhler graph, Figure 6.30 Ec2. Table 6.3N gives the values of $\Delta\sigma_{RSK}$, k_2, and N*. The factor γ_s is set to 1,15. $\Delta\sigma_{RSK}$ is the resisting stress range of the reinforcement.

Tabell 1 Resisting stress of reinforcment

$\Delta\sigma_{RSK}$ [MPa]	162,5
k_2	9
N*	10^6
γ_s	1,15

$N(\Delta\sigma_i)$ can then be found in Figure 6.30 using the stress, $\Delta\sigma$, for each axle load. The stress is assumed to vary linearly with the applied load. The stress is set for one of the axle loads, for example 4x140 kN, and gives the stress for the rest of the axle loads.

$n(\Delta\sigma_i)$ is divided by $N(\Delta\sigma_i)$ for each axle load and the quotients are summed up. If the sum is less than one the reinforcement capacity is large enough, if it isn't the amount of reinforcement has to be increased.

$$D_{Ed} = \sum_i \frac{n(\Delta\sigma_i)}{N(\Delta\sigma_i)} < 1 \qquad \text{Ec2, equation 6.70}$$

If the fatigue damage factor, D_{Ed}, does not satisfy the condition the value of $\Delta\sigma_{140}$ has to be adjusted until the fatigue damage factor is less than 1. Now, when the value of DEd is less than one, it's the value of $N(\Delta\sigma_i)$ for the stress given by 4x140 kN that is the input value that can be used in the box *Number of cycles.*

4.4.1.1 Calculation of $n(\Delta\sigma_i)$ according to Norwegian annex

n_{life} is given as the annual average daily traffic multiplied by the life and a factor to find the accurate number of cycles for fatigue load.

The fatigue load is divided into groups, depending on the axle load, with a specific share of the applied cycles. Each $n(\Delta\sigma_i)$ is then given as that share of n_{life}.

Table NA 4.6 – Model for fatigue load 3

Axle load [kN]	Share of n [%]
4x80	25
4x100	25
4x120	20
4x140	15
4x160	15

4.5 Rebar layers

In the *Rebar layer* dialogue you can choose the horizontal distance between the reinforcement bars in each layer. Set number of bars for a beam section. Set spacing for slab strips. If no input is given or the input is zero the number of bars in each layer is calculated by the program. The top row governs top reinforcement and the bottom row bottom reinforcement.

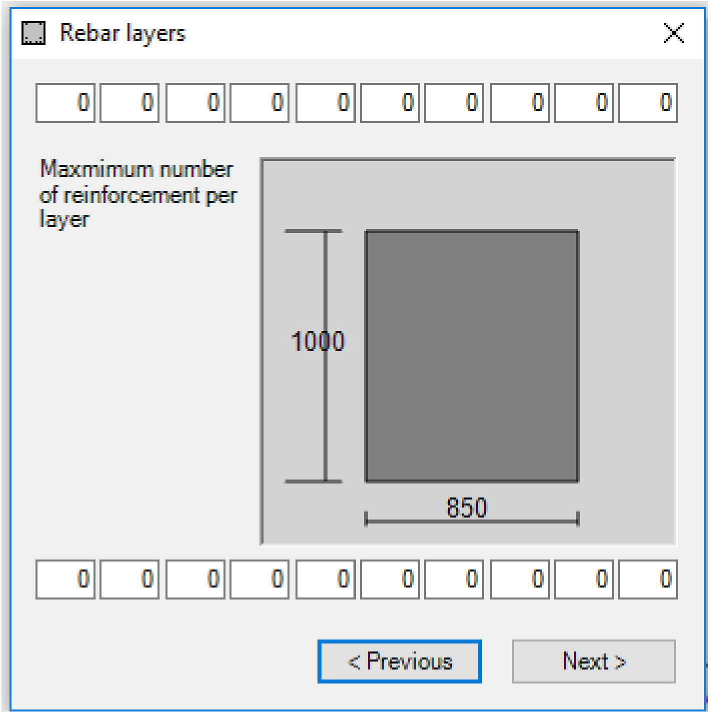


Figure 16 Rebar layer

5 Section forces

In the tab *Section forces* all sectional forces for ULS, SLS and fatigue can be found. The sectional forces are either read from the input file from Brigade or given manually, for example by copying and pasting form Excel, see chapter 5.1.

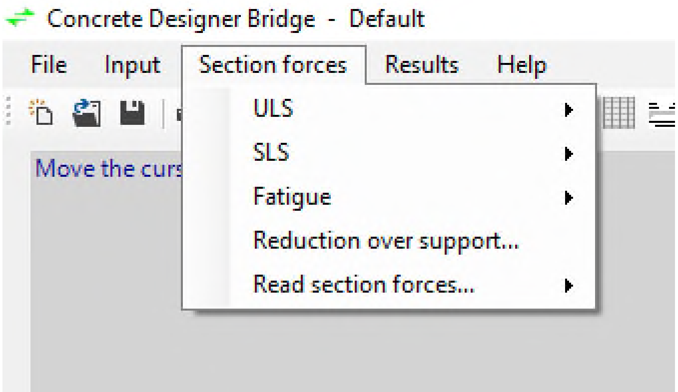


Figure 17 Section forces

The following can be done in all dialogues concerning sectional forces.

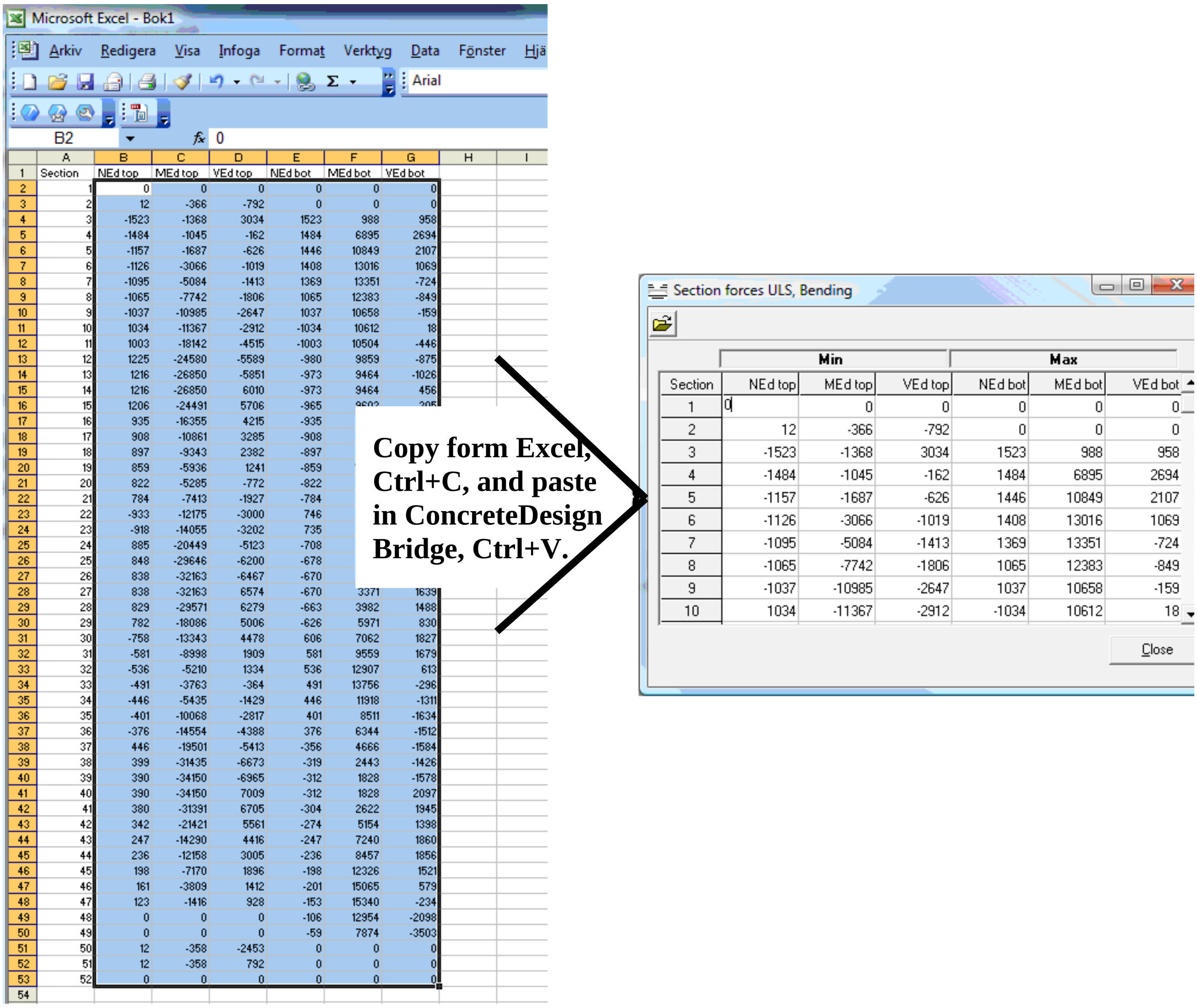
	Read sectional forces form a semicolon separated file.
	how sectional forces for the chosen line.
Ctrl+v	Paste sectional forces from Excel.

Notations used in the sectional forces dialogues:

NEd	Design axial force
MEd	Design moment
VEd	Design shear force
Fieff	Effective creep
TOP	Top (minimum graph)
BOT	Bottom (maximum graph)

5.1 Copy sectional forces form Excel

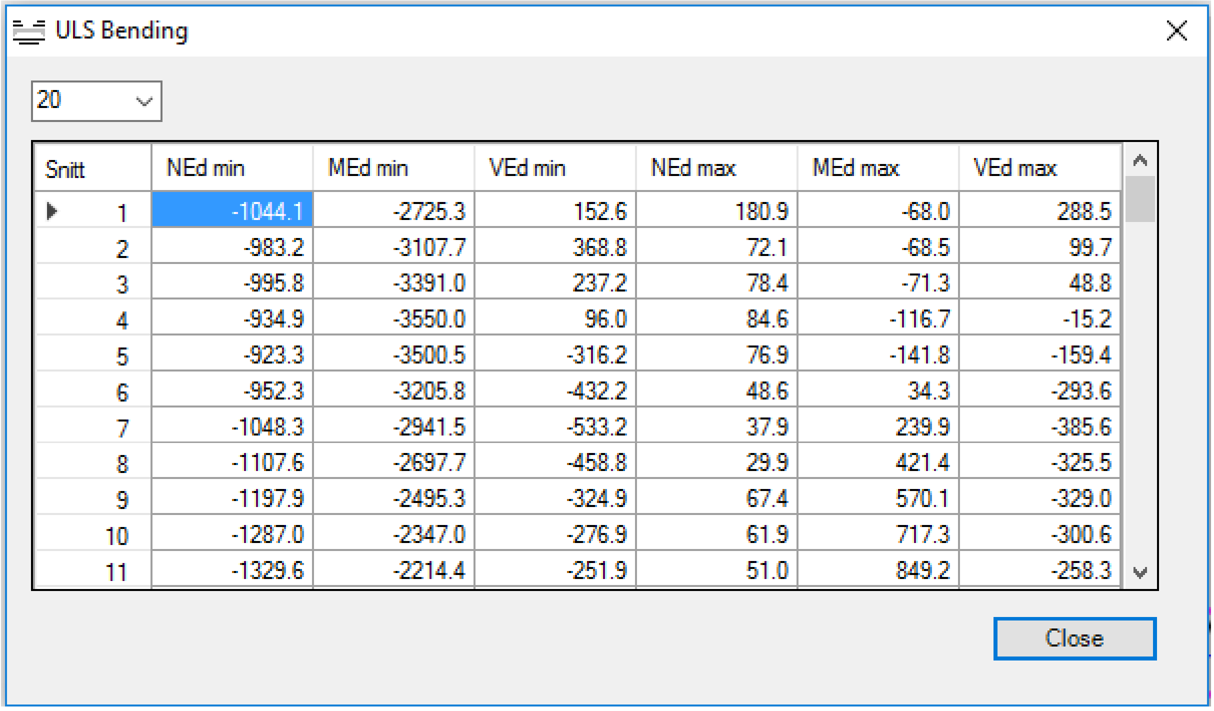
To copy sectional forces from an Excel file to one of the sectional forces dialogues, just mark the area you want to copy, copy and paste. Note that the number of columns in Excel and *ConcreteDesign Bridge* has to be the same.



5.2 ULS

Under the tab ULS the sectional forces are shown in ultimate limit state. Design values of axial forces, moments and shear forces are given for both bending and shear.

5.2.1 Bending



Snitt	NEd min	MEd min	VEd min	NEd max	MEd max	VEd max
1	-1044.1	-2725.3	152.6	180.9	-68.0	288.5
2	-983.2	-3107.7	368.8	72.1	-68.5	99.7
3	-995.8	-3391.0	237.2	78.4	-71.3	48.8
4	-934.9	-3550.0	96.0	84.6	-116.7	-15.2
5	-923.3	-3500.5	-316.2	76.9	-141.8	-159.4
6	-952.3	-3205.8	-432.2	48.6	34.3	-293.6
7	-1048.3	-2941.5	-533.2	37.9	239.9	-385.6
8	-1107.6	-2697.7	-458.8	29.9	421.4	-325.5
9	-1197.9	-2495.3	-324.9	67.4	570.1	-329.0
10	-1287.0	-2347.0	-276.9	61.9	717.3	-300.6
11	-1329.6	-2214.4	-251.9	51.0	849.2	-258.3

Figure 18 ULS bending

List a list of picked result lines from BRIDGADE

Snitt(section)amount of section in each result line.

N_{Ed} **min** minimum value of applied axial force

M_{Ed} **min** minimum value of applied moment

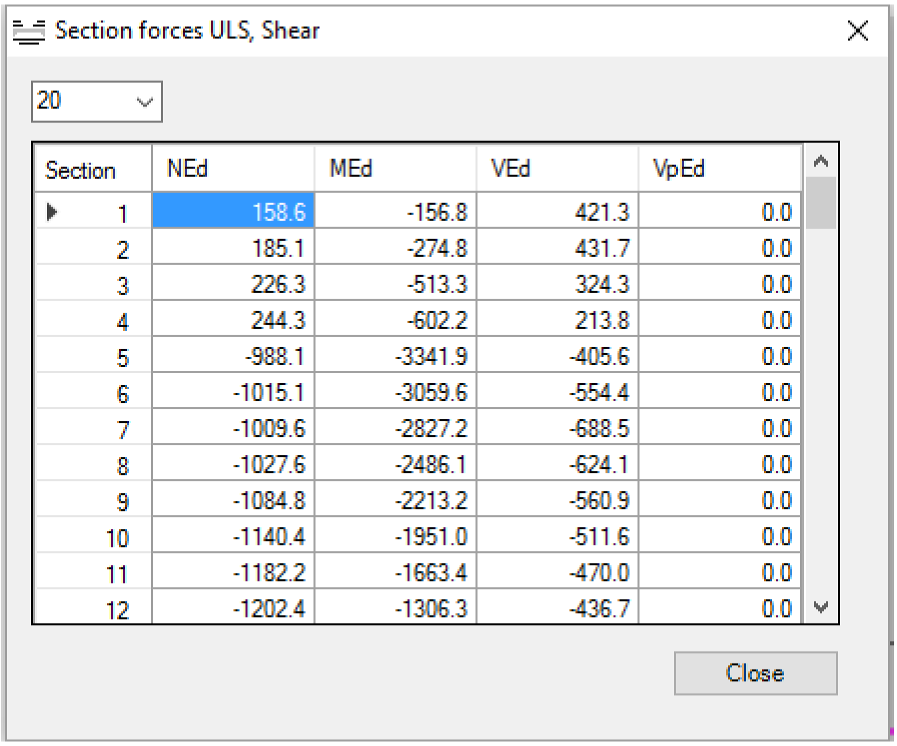
V_{Ed} **min** minimum value of applied shear force

N_{Ed} **max** maximum value of applied axial force

M_{Ed} **max** maximum value of applied moment

V_{Ed} **max** maximum value of applied shear force

5.2.2 Shear



Section	NEd	MEd	VEd	VpEd
1	158.6	-156.8	421.3	0.0
2	185.1	-274.8	431.7	0.0
3	226.3	-513.3	324.3	0.0
4	244.3	-602.2	213.8	0.0
5	-988.1	-3341.9	-405.6	0.0
6	-1015.1	-3059.6	-554.4	0.0
7	-1009.6	-2827.2	-688.5	0.0
8	-1027.6	-2486.1	-624.1	0.0
9	-1084.8	-2213.2	-560.9	0.0
10	-1140.4	-1951.0	-511.6	0.0
11	-1182.2	-1663.4	-470.0	0.0
12	-1202.4	-1306.3	-436.7	0.0

Figure 19 ULS Shear

List a list of picked result lines from BRIDGADE

N_{Ed} design value of applied axial force

M_{Ed} design value of applied moment

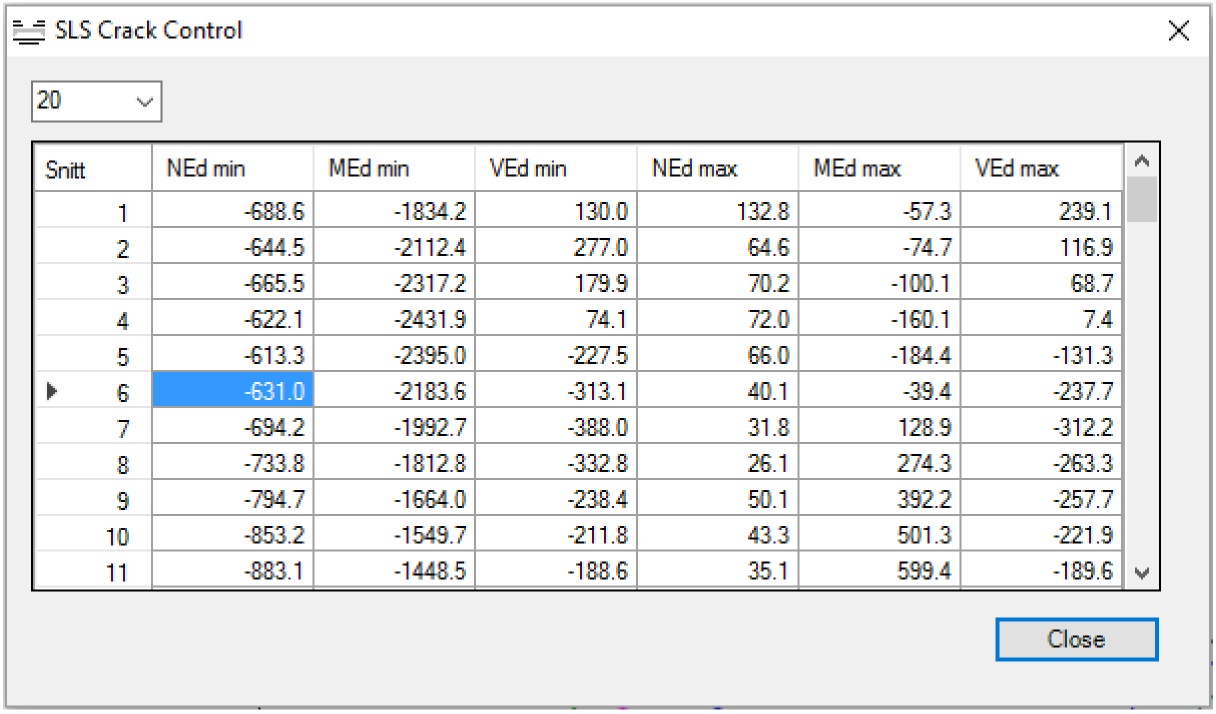
V_{Ed} design value of applied shear force

V_{pEd} design value of applied shear force perpendicular

5.3 SLS

Under the tab SLS the sectional forces used to control cracking and calculate crack width caused by bending are shown, that is serviceability limit state. In both cases axial forces, moments, and effective creep are given.

5.3.1 Crack control



Snitt	NEd min	MEd min	VEd min	NEd max	MEd max	VEd max
1	-688.6	-1834.2	130.0	132.8	-57.3	239.1
2	-644.5	-2112.4	277.0	64.6	-74.7	116.9
3	-665.5	-2317.2	179.9	70.2	-100.1	68.7
4	-622.1	-2431.9	74.1	72.0	-160.1	7.4
5	-613.3	-2395.0	-227.5	66.0	-184.4	-131.3
6	-631.0	-2183.6	-313.1	40.1	-39.4	-237.7
7	-694.2	-1992.7	-388.0	31.8	128.9	-312.2
8	-733.8	-1812.8	-332.8	26.1	274.3	-263.3
9	-794.7	-1664.0	-238.4	50.1	392.2	-257.7
10	-853.2	-1549.7	-211.8	43.3	501.3	-221.9
11	-883.1	-1448.5	-188.6	35.1	599.4	-189.6

Figure 20 SLS Crack control data

List a list of picked result lines from BRIDGADE

Snitt(section)amount of section in each result line.

N_{Ed} **min** minimum value of applied axial force

M_{Ed} **min** minimum value of applied moment

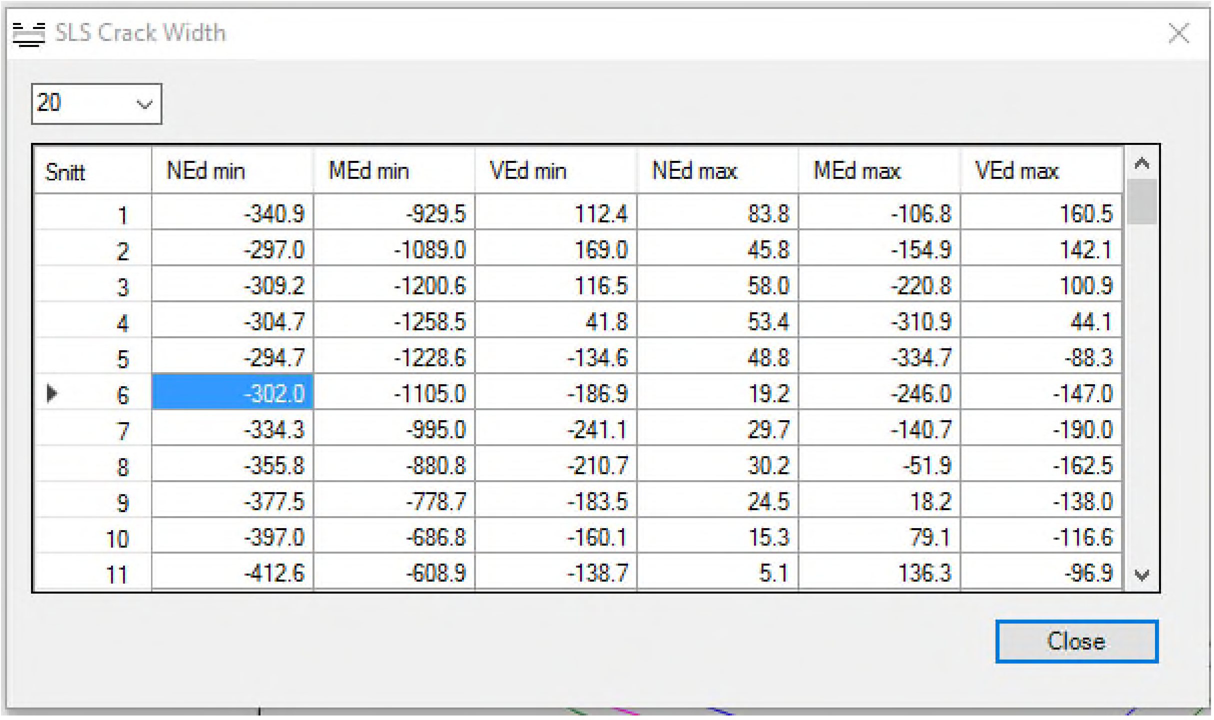
V_{Ed} **min** minimum value of applied shear force

N_{Ed} **max** maximum value of applied axial force

M_{Ed} **max** maximum value of applied moment

V_{Ed} **max** maximum value of applied shear force

5.3.2 Crack width



Snitt	NEd min	MEd min	VEd min	NEd max	MEd max	VEd max
1	-340.9	-929.5	112.4	83.8	-106.8	160.5
2	-297.0	-1089.0	169.0	45.8	-154.9	142.1
3	-309.2	-1200.6	116.5	58.0	-220.8	100.9
4	-304.7	-1258.5	41.8	53.4	-310.9	44.1
5	-294.7	-1228.6	-134.6	48.8	-334.7	-88.3
6	-302.0	-1105.0	-186.9	19.2	-246.0	-147.0
7	-334.3	-995.0	-241.1	29.7	-140.7	-190.0
8	-355.8	-880.8	-210.7	30.2	-51.9	-162.5
9	-377.5	-778.7	-183.5	24.5	18.2	-138.0
10	-397.0	-686.8	-160.1	15.3	79.1	-116.6
11	-412.6	-608.9	-138.7	5.1	136.3	-96.9

Figure 21 SLS Crack width data

List a list of picked result lines from BRIDGADE

Snitt(section) amount of section in each result line.

N_{Ed} **min** minimum value of applied axial force

M_{Ed} **min** minimum value of applied moment

V_{Ed} **min** minimum value of applied shear force

N_{Ed} **max** maximum value of applied axial force

M_{Ed} **max** maximum value of applied moment

V_{Ed} **max** maximum value of applied shear force

5.4 Fatigue

The sectional forces used to calculate fatigue because of permanent, variable and cyclic loads in both bending and shear can be found here.

Fatigue is calculated according to the choice of method, *Road bridge, Railway bridge* or *Palmgren-Miner rule* done in the menu *Parameters,* chapter 4.5.

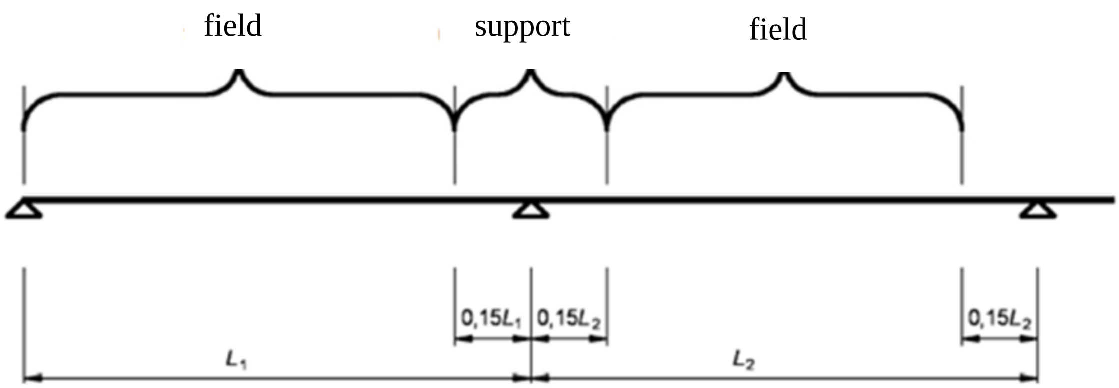
The check is based on sectional forces from the different basic load combinations where design moments for reinforcement are used for variable and cyclic loads only. For permanent loads pure bending is used instead.

The summation of the load effects is done by ConcreteDesign Bridge and type of load, distance to support etc is regarded. The partial coefficient used is presented in the section *Fatigue, Sections forces bending reinforcement* in the report.

The following partial coefficients are used for fatigue control of road bridges see Ec2 NN.2.1 (101):

Control	Permanent loads	Variable loads	Cyclic loads
Concrete, bending	**1,0**	**1,0**	**1,0**
Reinforcement, bending	**1,0**	**0,0**	**1,4/1,75**[1]
Concrete, shear	**1,0**	**1,0**	**1,0**
Reinforcement, shear	**1,0**	**0,0**	**1,4/1,75**[1]

[1] 1,75 at intermediate support according to the Figure below

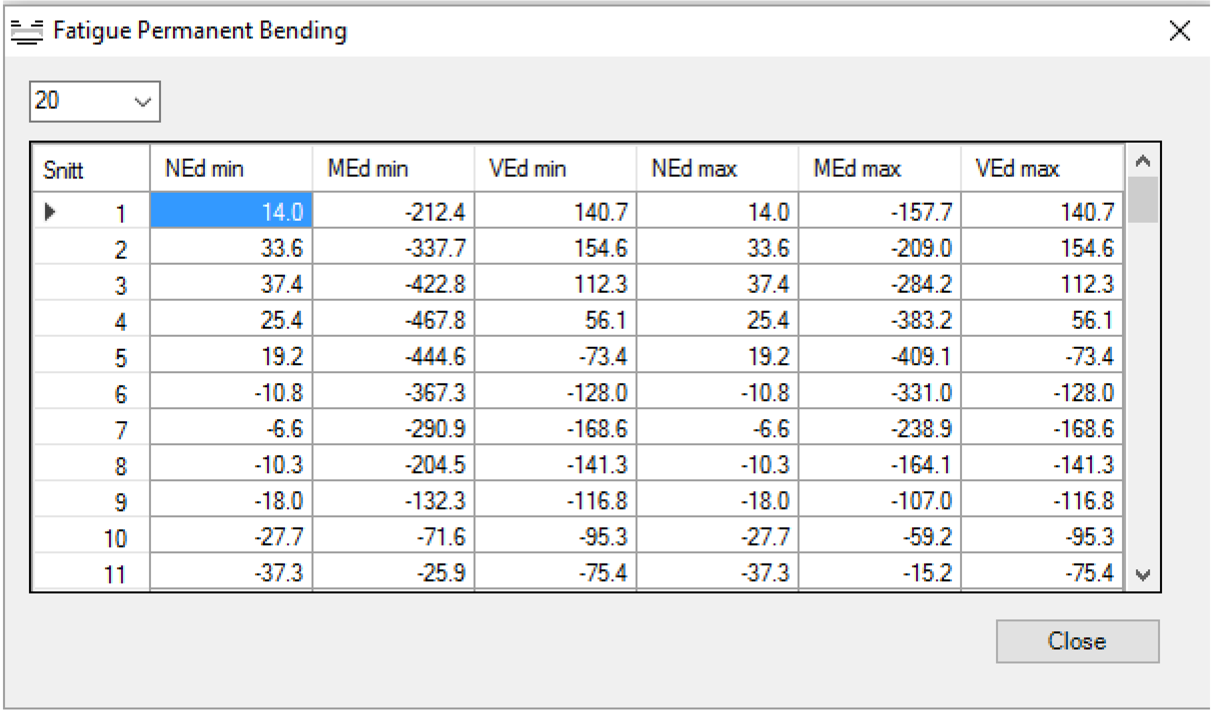


The following partial coefficients are used for load combinations in fatigue control of railway bridges.

Control	Permanent loads	Variable loads	Cyclic loads
Concrete, bending	**1,0**	**0,0**	**1,0**
Reinforcement, bending	**1,0**	**0,0**	**1,0**
Concrete, shear	**1,0**	**0,0**	**1,0**
Reinforcement, shear	**1,0**	**0,0**	**1,0**

5.4.1 Bending

Shows bending stresses. The calculation of the variation in bending stress is described below and done using input from Brigade.



Snitt	NEd min	MEd min	VEd min	NEd max	MEd max	VEd max
1	14.0	-212.4	140.7	14.0	-157.7	140.7
2	33.6	-337.7	154.6	33.6	-209.0	154.6
3	37.4	-422.8	112.3	37.4	-284.2	112.3
4	25.4	-467.8	56.1	25.4	-383.2	56.1
5	19.2	-444.6	-73.4	19.2	-409.1	-73.4
6	-10.8	-367.3	-128.0	-10.8	-331.0	-128.0
7	-6.6	-290.9	-168.6	-6.6	-238.9	-168.6
8	-10.3	-204.5	-141.3	-10.3	-164.1	-141.3
9	-18.0	-132.3	-116.8	-18.0	-107.0	-116.8
10	-27.7	-71.6	-95.3	-27.7	-59.2	-95.3
11	-37.3	-25.9	-75.4	-37.3	-15.2	-75.4

Figure 22 Permanent bending

The calculation of variation in bending stress in the longitudinal direction of the bridge is based on the following moments:

If $| \Sigma^{Perm}\ Ma + \Sigma^{Var}\ MRL+_{max} | > | \Sigma^{Perm}\ Ma + \Sigma^{Var}\ MRL-_{min} |$

$M_{max} = \Sigma^{Perm}\ Ma + \Sigma^{Var}\ MRL+_{max} + \Sigma^{Cykl} MRL+_{max}$

$M_{min} = \Sigma^{Perm}\ Ma + \Sigma^{Var}\ MRL+_{max} + \Sigma^{Cykl} MRL-_{min}$

else

$M_{max} = \Sigma^{Perm}\ Ma + \Sigma^{Var}\ MRL-_{min} + \Sigma^{Cykl} MRL+_{max}$

$M_{min} = \Sigma^{Perm}\ Ma + \Sigma^{Var}\ MRL-_{min} + \Sigma^{Cykl} MRL-_{min}$

The calculation of variation in bending stress in the transverse direction of the bridge is based on the following moments:

If $| \Sigma^{Perm}\ Ms + \Sigma^{Var}\ MRT+_{max} | > | \Sigma^{Perm}\ Ms + \Sigma^{Var}\ MRT-_{min} |$

$M_{max} = \Sigma^{Perm}\ Ms + \Sigma^{Var}\ MRT+_{max} + \Sigma^{Cykl} MRT+_{max}$

$M_{min} = \Sigma^{Perm}\ Ms + \Sigma^{Var}\ MRT+_{max} + \Sigma^{Cykl} MRT-_{min}$

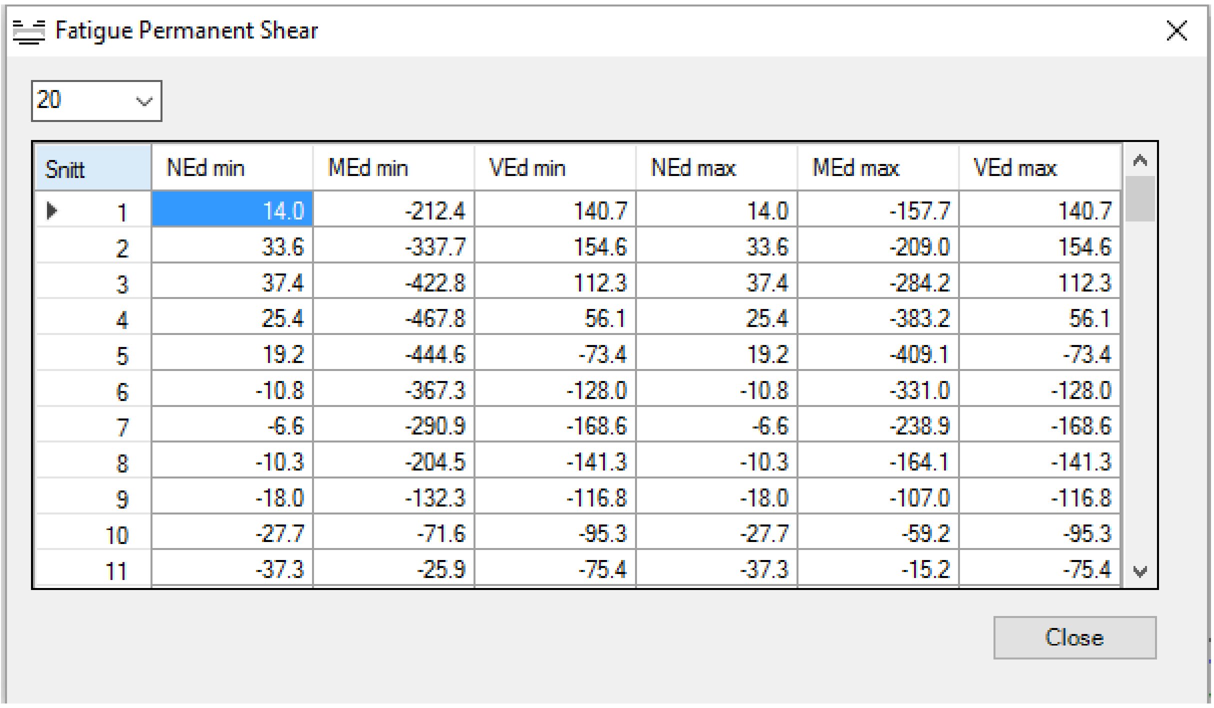
else

$M_{max} = \Sigma^{Perm}\ Ms + \Sigma^{Var}\ MRT-_{min} + \Sigma^{Cykl} MRT+_{max}$

$M_{min} = \Sigma^{Perm}\ Ms + \Sigma^{Var}\ MRT-_{min} + \Sigma^{Cykl} MRT-_{min}$

5.4.2 Permanent Shear

Shows shear stresses. The calculation of the variation in shear stress is described below and done using input from Brigade.



Snitt	NEd min	MEd min	VEd min	NEd max	MEd max	VEd max
1	14.0	-212.4	140.7	14.0	-157.7	140.7
2	33.6	-337.7	154.6	33.6	-209.0	154.6
3	37.4	-422.8	112.3	37.4	-284.2	112.3
4	25.4	-467.8	56.1	25.4	-383.2	56.1
5	19.2	-444.6	-73.4	19.2	-409.1	-73.4
6	-10.8	-367.3	-128.0	-10.8	-331.0	-128.0
7	-6.6	-290.9	-168.6	-6.6	-238.9	-168.6
8	-10.3	-204.5	-141.3	-10.3	-164.1	-141.3
9	-18.0	-132.3	-116.8	-18.0	-107.0	-116.8
10	-27.7	-71.6	-95.3	-27.7	-59.2	-95.3
11	-37.3	-25.9	-75.4	-37.3	-15.2	-75.4

Figure 23 Permanent shear

The calculation of variation in shear stress along the bridge in longitudinal direction is based on the following shear forces:

If $\left| \Sigma^{Perm} Vsz + \Sigma^{Var} Vsz_{max} \right| > \left| \Sigma^{Perm} Vsz + \Sigma^{Var} Vsz_{min} \right|$

$$Vsz_{max} = \Sigma^{Perm} Vsz + \Sigma^{Var} Vsz_{max} + \Sigma^{Cykl} Vsz_{max}$$

$$Vsz_{min} = \Sigma^{Perm} Vsz + \Sigma^{Var} Vsz_{max} + \Sigma^{Cykl} Vsz_{min}$$

else

$$Vsz_{max} = \Sigma^{Perm} Vsz + \Sigma^{Var} Vsz_{min} + \Sigma^{Cykl} Vsz_{max}$$

$$Vsz_{min} = \Sigma^{Perm} Vsz + \Sigma^{Var} Vsz_{min} + \Sigma^{Cykl} Vsz_{min}$$

The calculation of variation in shear stress in the transverse direction of the bridge is based on the following shear forces:

If $\left| \Sigma^{Perm} Vaz + \Sigma^{Var} Vaz_{max} \right| > \left| \Sigma^{Perm} Vaz + \Sigma^{Var} Vaz_{min} \right|$

$$Vaz_{max} = \Sigma^{Perm} Vaz + \Sigma^{Var} Vaz_{max} + \Sigma^{Cykl} Vaz_{max}$$

$$Vaz_{min} = \Sigma^{Perm} Vaz + \Sigma^{Var} Vaz_{max} + \Sigma^{Cykl} Vaz_{min}$$

else

$$Vaz_{max} = \Sigma^{Perm} Vaz + \Sigma^{Var} Vaz_{min} + \Sigma^{Cykl} Vaz_{max}$$

$$Vaz_{min} = \Sigma^{Perm} Vaz + \Sigma^{Var} Vaz_{min} + \Sigma^{Cykl} Vaz_{min}$$

This method is described in Ec2 chapter 6.8.4 (2).

5.5 Reduction over support

It is possible to choose to reduce moments and/or shear forces over supports.

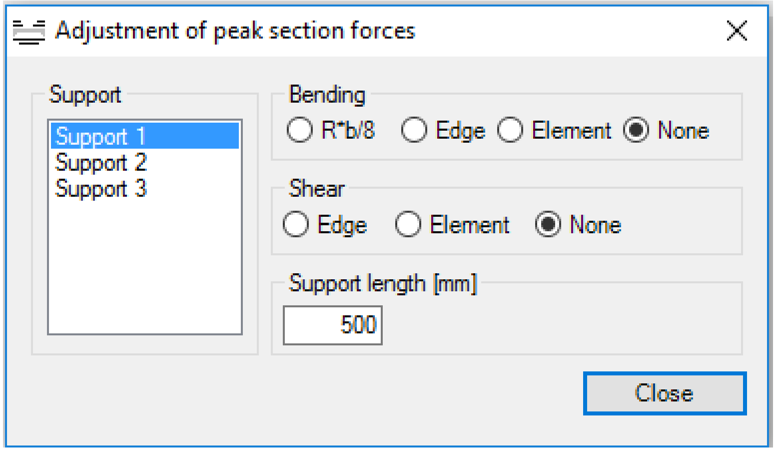


Figure 24 Adjustment of peak section forces

R*b/8	The moment is rounded down by R*b/8, where R=sum of shear forces on both sides of the support
Edge	Used at the end of the support, the sectional force in the section is interpolated by the program
Element	At the edge of the element. The sectional force is chosen in the next section to the left or right of the support section. The bigger of these two values is used.
None	No reduction
Support length	Length of the support. Used if choosing R*b/8 or Edge.

5.6 Read section forces

At *Read section forces* sectional forces can be read from [Input_file].xml.

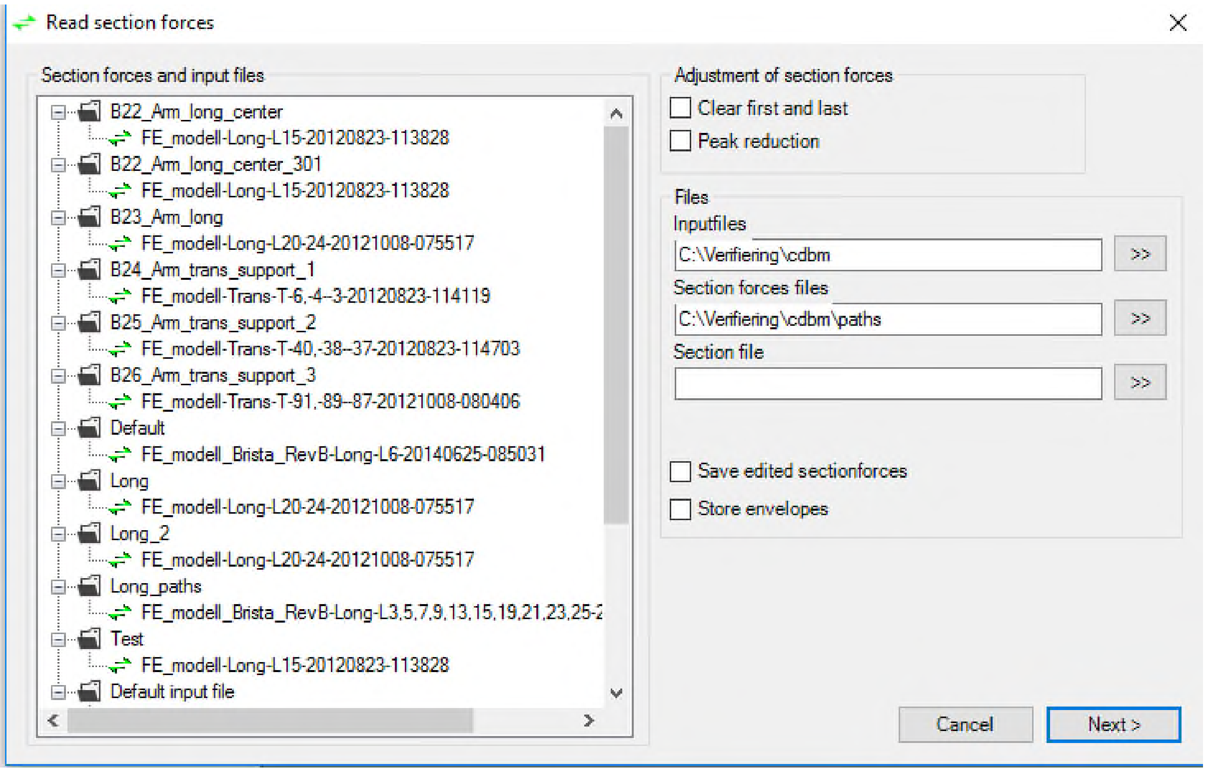
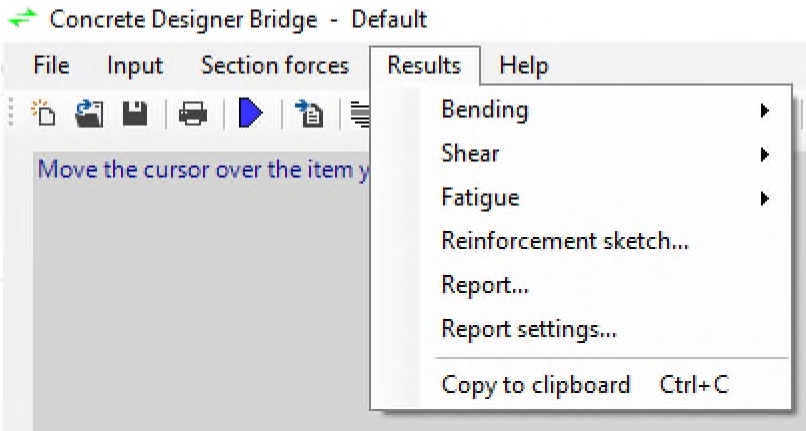


Figure 25 Read section forces

File for section forces	File including sectional forces.
Adjustment of section forces	If there are extreme values in the first and last section it is possible to set these as zero. It is also possible to reduce top values.
Input files	Files that contain information about material properties, SLS and Fatigue design parameters and reinforcement arrangement.
Section forces files	Geometric data and sections forces from BRIGADE.
	Change section force file.

6 Results



Buttons in the dialogues

 Copy a picture to the clipboard

 Print

 Diagram settings

 Arrange reinforcement

You choose what results will be shown in each menu by clicking *Settings.*

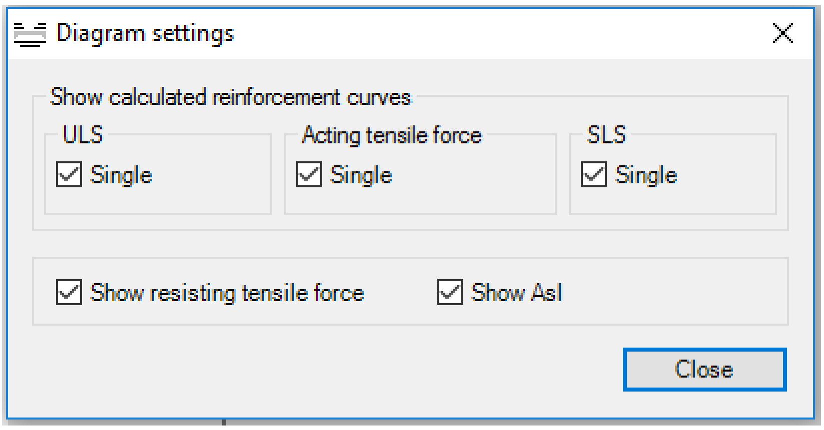


Figure 26 Diagram settings

You can choose to show:

Max/min graphs Graphs showing the maximum reinforcement amount needed for the lines.

Average graphs Graphs showing average values of reinforcement need for the lines.

Single graphs Needed reinforcement for chosen lines in the list *Show lines.*

Resisting tensile force	Graph that covers the need for reinforcement, presenting the reinforcement given in the dialogues *Bending reinforcement* and *Shear reinforcement*.

6.1 Bending

Under bending you can choose to show moment graphs, needed reinforcement or a reinforcement sketch. You can also rearrange the reinforcement bars.

6.1.1 Design forces

This window shows the bending moments. Except the buttons described above you can also zoom. Number of lines show on diagram is according to how many path you created in the earlier steps.

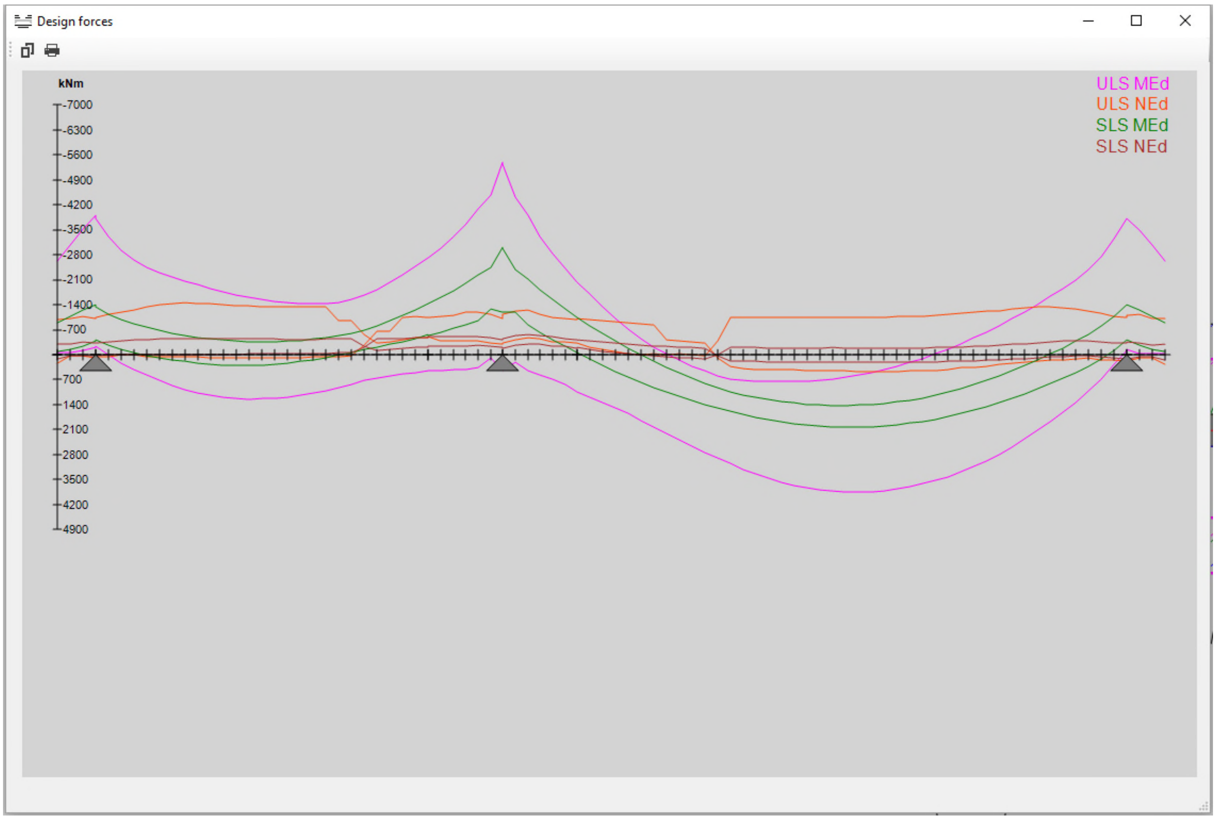


Figure 27 Design forces diagram

Design moment graph

ULS M_{Ed}	Moment in ultimate limit state
ULS N_{Ed}	Normal forces in Ultimate limit state
SLS M_{Ed}	Moment in Serviceability limit state
SLS N_{Ed}	Normal forces in Serviceability limit state

6.1.2 Reinforcement

This window shows the reinforcement required in ultimate, serviceability limit state, fatigue and the capacity of the chosen reinforcement. You can also zoom by using the *ctrl+mouse wheel*. By clicking *Arrange rebars* it is possible to rearrange the reinforcement.

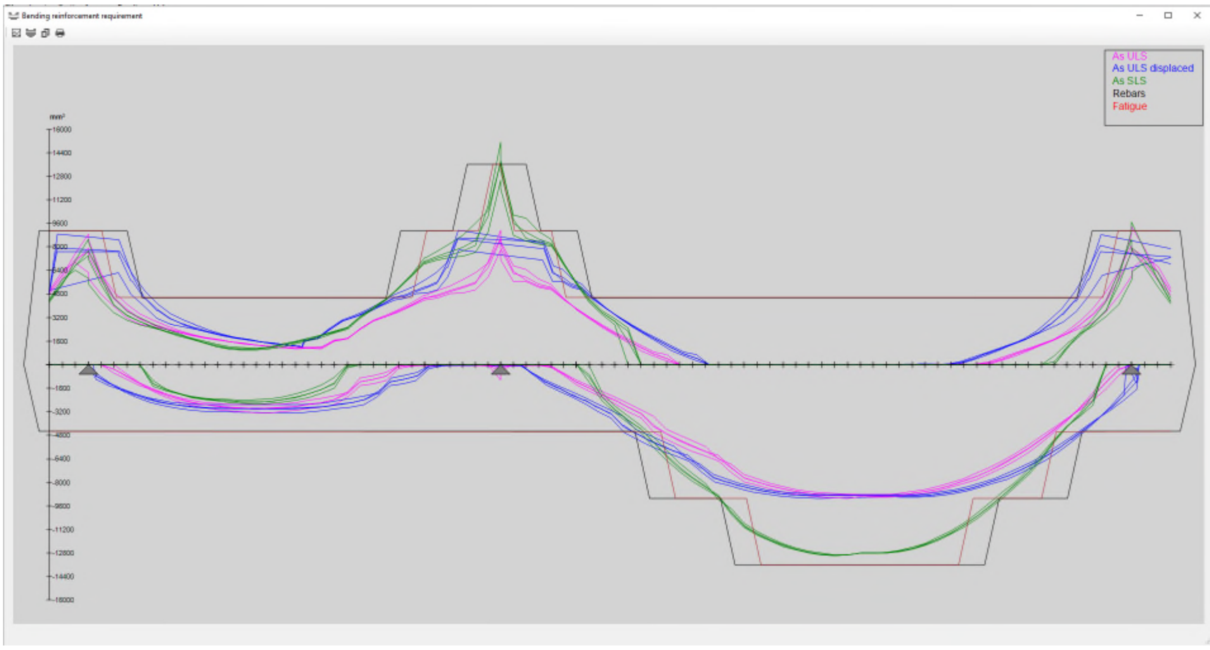


Figure 28 Reinforcement diagram

Reinforcement graph

As,ULS	Reinforcement required in ULS
As ULS Displaced	Shifted ULS graph
As SLS	Reinforcment required in SLS
Rebars	Applied reinforcement
Fatigue	Fatigue across entire bridge

6.1.2.1 Arrange rebars

Arrange rebars

By clicking the *Arrange rebars*-button, shown above, you reach this window.

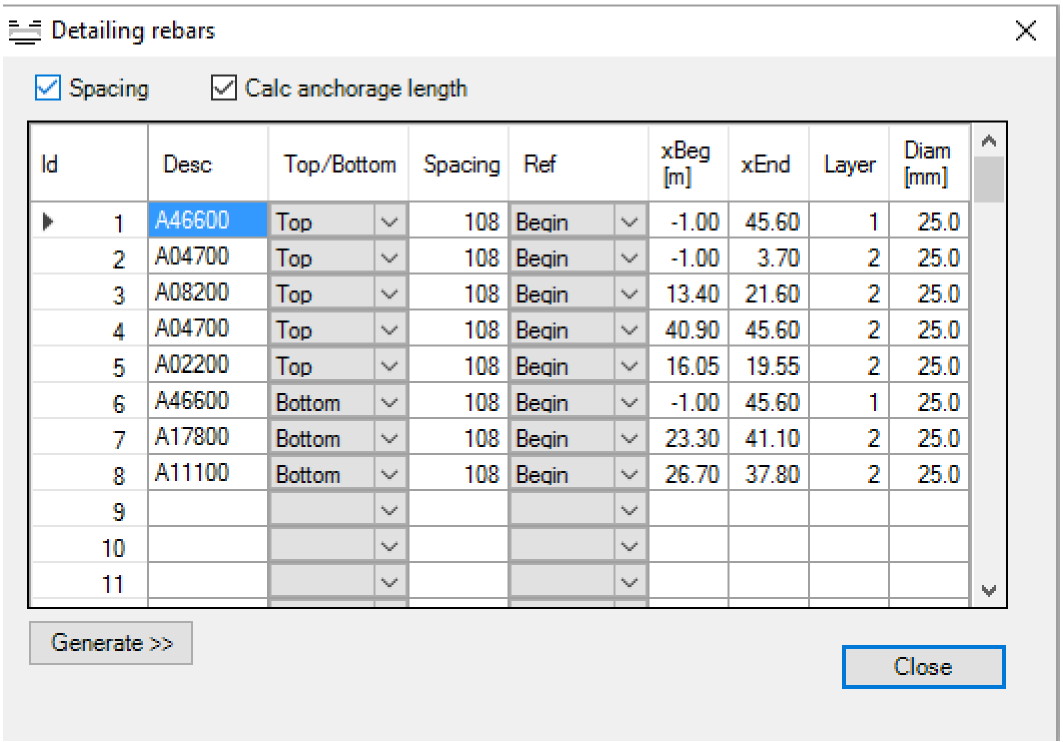
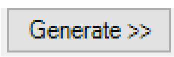


Figure 29 Stirrup

Desc	Description
Top/Bot	Top or Bottom
Spacing	Spacing betweern each stirrup
Area	Reinforcement area [mm^2]
Ref	References of reinforcements position
xBeg	First coordinate, reinforcement [m].
xEnd	Last coordinate, reinforcement [m].
Layer	Reinforcement layer. Used to calculate anchorage.
Diam	Reinforcement diameter [mm]
Edge dist.	Distance between edge and reinforcement. Used to calculate anchorage.



Generate rebar location; set Area per module to the available area in each layer. Also, set Resisting curve as max or average depending on if you want the reinforcement to cover maximum or average requirements. The window to the right can be used as guidance to what area is given by a certain diameter and spacing of the reinforcement.

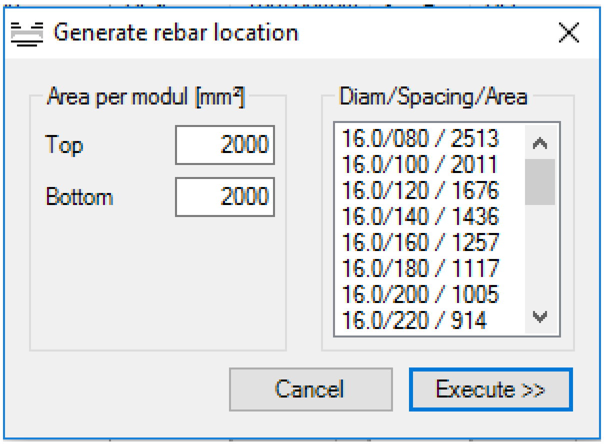


Figure 30 Generate rebar location

6.1.3 Reinforcement specification

Shows reinforcement specification.

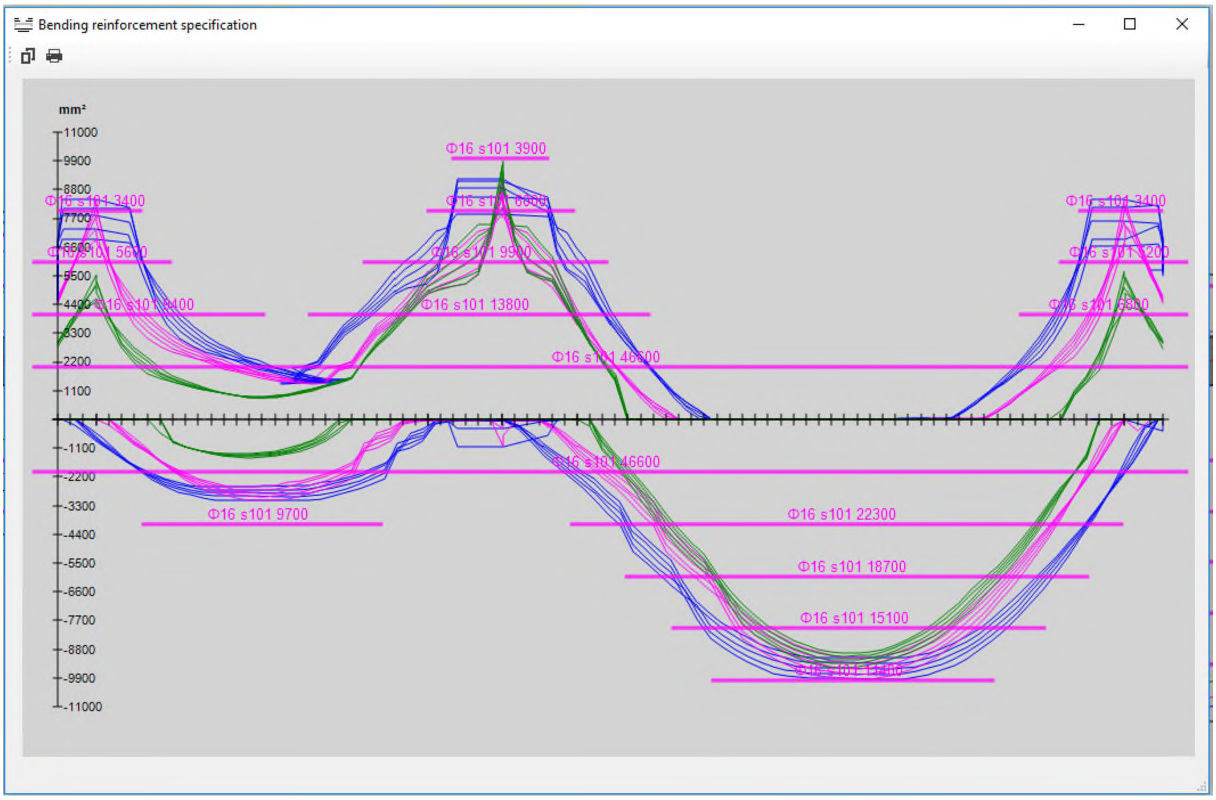


Figure 31 Diagram of bending reinforcement specification

6.2 Shear

Shows shear force graphs and required shear reinforcement.

6.2.1 Design forces

This graph shows the load effect of the shear force, the concrete capacity and required reinforcement.

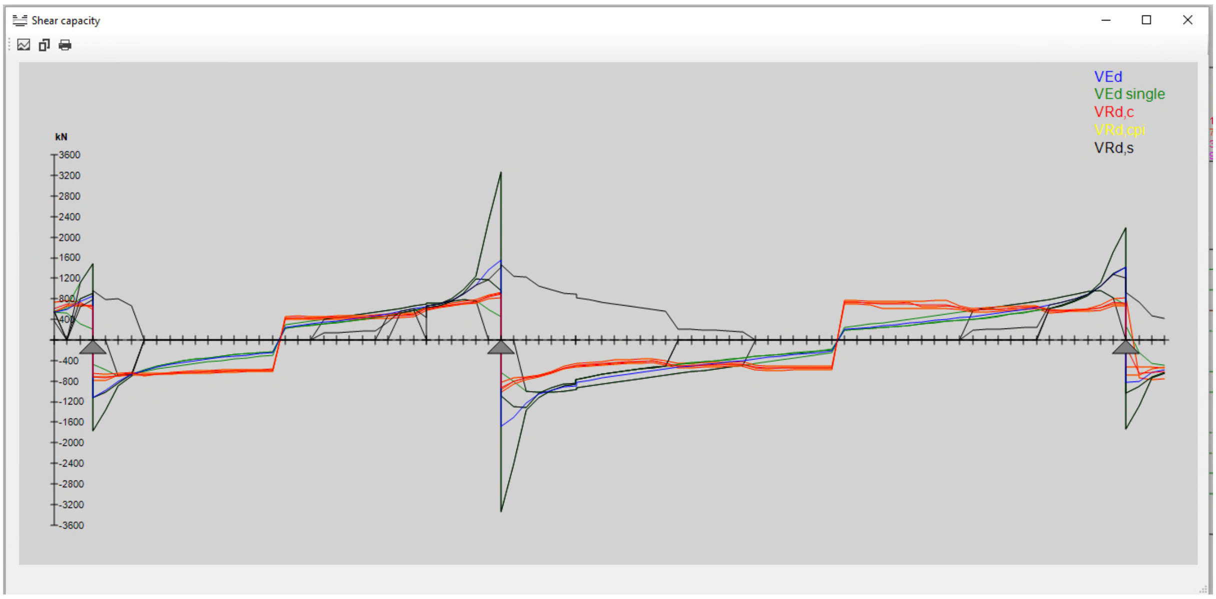


Figure 32 Shear Capacity

Shear force and shear force capacity Eq 6.1-6.2a/b

$\mathbf{V_{Ed}}$	Design shear force.
$\mathbf{V_{Ed,Single}}$	Single line shear force capacity.
$\mathbf{V_{Rd,c}}$	Concrete shear force capacity.
$\mathbf{V_{Rd,s}}$	Steel shear force capacity.
$\mathbf{V_{Rd,i}}$	Inclined shear force capacity.
$\mathbf{V_{Rd,p}}$	Axial force.

6.2.2 Reinforcement

This graph shows the required reinforcement with regard to shear such as the applied reinforcement.

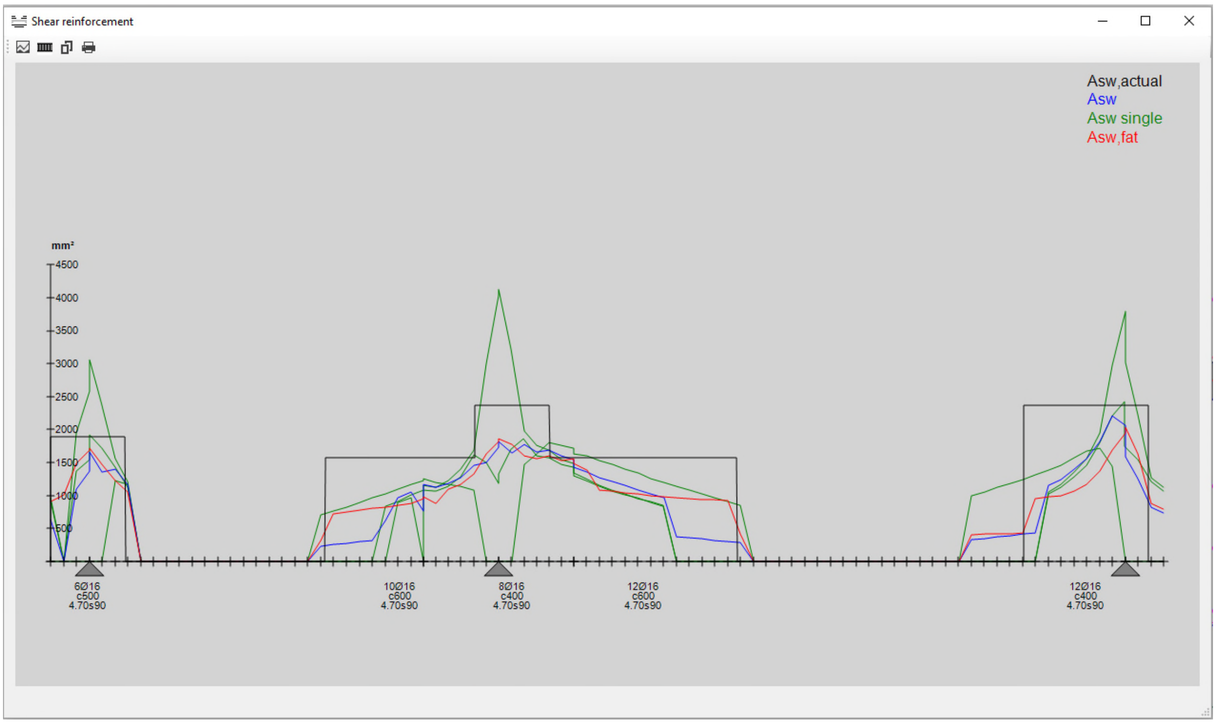


Figure 33 Shear reinforcment diagram

Shear reinforcement graph

Asw	Required reinforcement with regard to shear force.
Asw,fat	Required reinforcement with regard to fatigue.
Asw, Actual	Applied shear reinforcement.
Asw single	Single line reinforcement with regard to shear force.

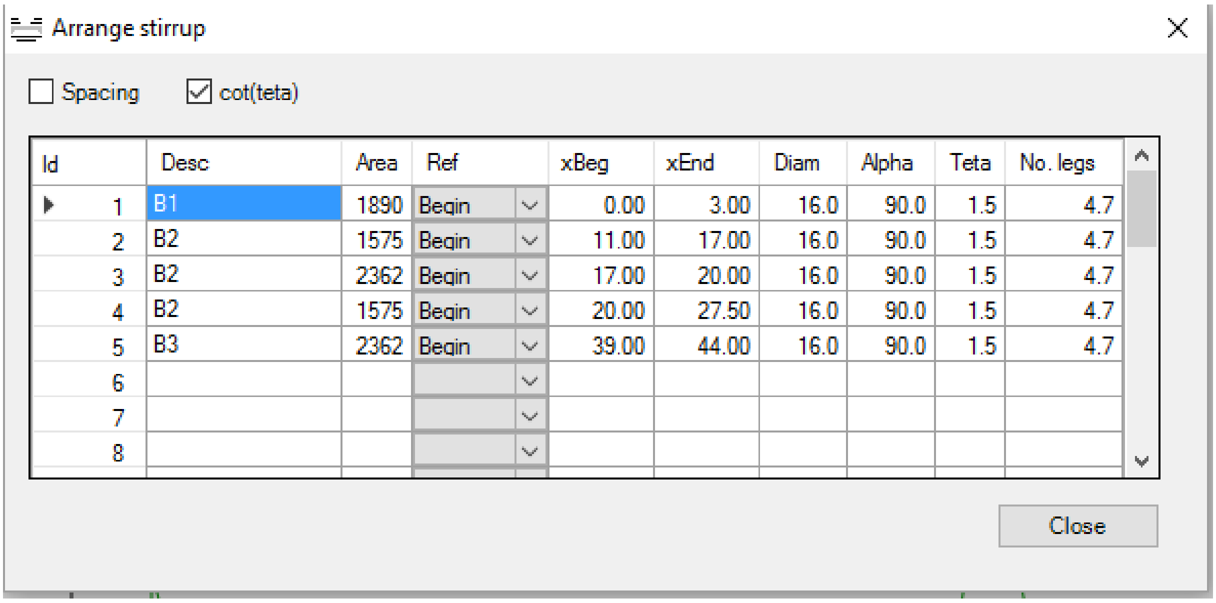
Example:

4Φ16	4 stirrups, Φ16
C500	Spacing 500mm
4S90	4 legged stirrups, angle 90 degrees

6.2.2.1 6.2.2.1Arrange stirrup

Arrange stirrup

The *Arrange stirrup* –button, shown above, takes you to this window, where it is possible to rearrange shear reinforcement and change settings for reinforcement diameter and the inclination of the struts and stirrups.



Id	Desc	Area	Ref	xBeg	xEnd	Diam	Alpha	Teta	No. legs
1	B1	1890	Begin	0.00	3.00	16.0	90.0	1.5	4.7
2	B2	1575	Begin	11.00	17.00	16.0	90.0	1.5	4.7
3	B2	2362	Begin	17.00	20.00	16.0	90.0	1.5	4.7
4	B2	1575	Begin	20.00	27.50	16.0	90.0	1.5	4.7
5	B3	2362	Begin	39.00	44.00	16.0	90.0	1.5	4.7
6									
7									
8									

Figure 34 Stirrup

Desc	Description
Area/Spacing	Reinforcement area [mm^2] or spacing (change by checking the box in the top left corner)
Ref	Categorize several range of the brigde
Xbeg	First coordinate of the reinforcement [m]
xEnd	Last coordinate of the reinforcement [m]
Diam	Reinforcement diameter [mm]
Alpha	Inclination of stirrup [deg]
Teta	Inclination of strut in [deg] or cot(teta), check the box to change
No Legs	Number of legs

6.3 *Fatigue*

Shows reinforcement requirements with regard to fatigue.

6.3.1 Fatigue bending reinforcement

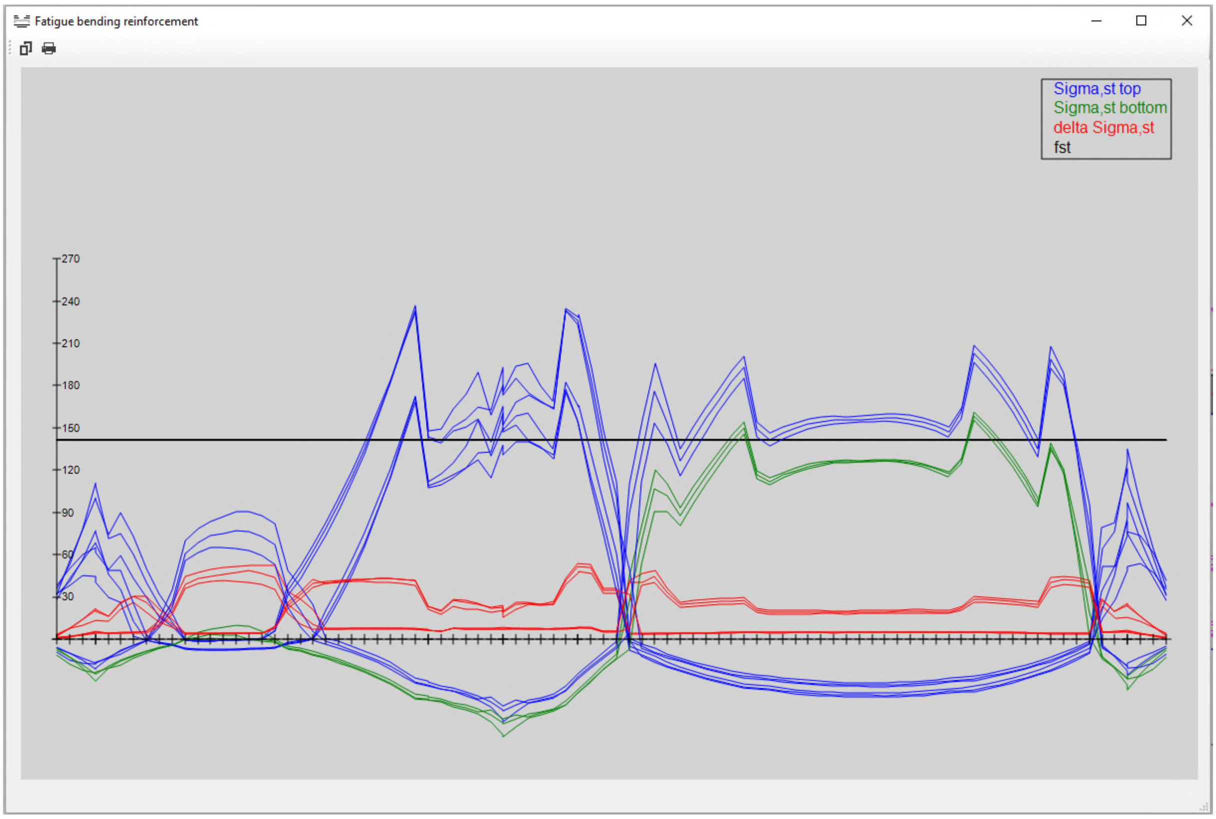


Figure 35 Fatigue bending reinforcment

Sigma,st top	Steel stress, top
Sigma,st bottom	Steel stress, bottom
delta Sigma,st	Stress range
fst	Design stress range (maximum)

6.4 Report

Creates a report including all results. Detailed information about the report can be found in chapter 8.

6.5 Print Selection

Under *print selection* you have the opportunity to choose different graphics which is presentation on the report and the *Design forces* diagrams for Bending and *Shear*.

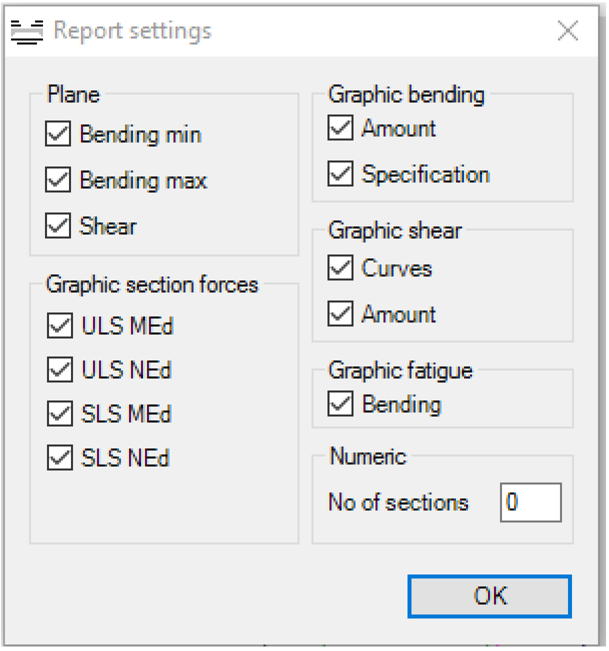


Figure 36 Print selection

ULS bending

Requirement	Include a_s-calculated in graphics
Specification	Include arranged reinforcement

ULS shear

Requirement	Include a_{sv}-calculated in graphics
Specification	Include arranged stirrups

SLS bending

Crack control	Include Crack control

Fatigue

Graphics	Include fatigue graphics

Plane (reinforcement plane graph)

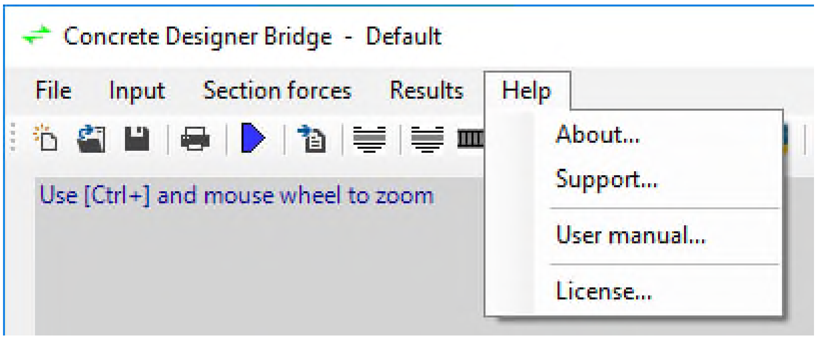
Bending min	Include bending max
Bending max	Include bending min
Shear	Include shear

Graphic section forces (section forces in diagrams)

ULS MEd	Include ULS M_{Ed}
ULS NEd	Include ULS N_{Ed}
SLS MEd	Include SLS M_{Ed}
SLS NEd	Include SLS N_{Ed}

Numeric	Number of sections to be presented between supports. Give a high value, for example 99, to include all sections.

7 Help



7.1 About

At *About* a short description of the program is available.

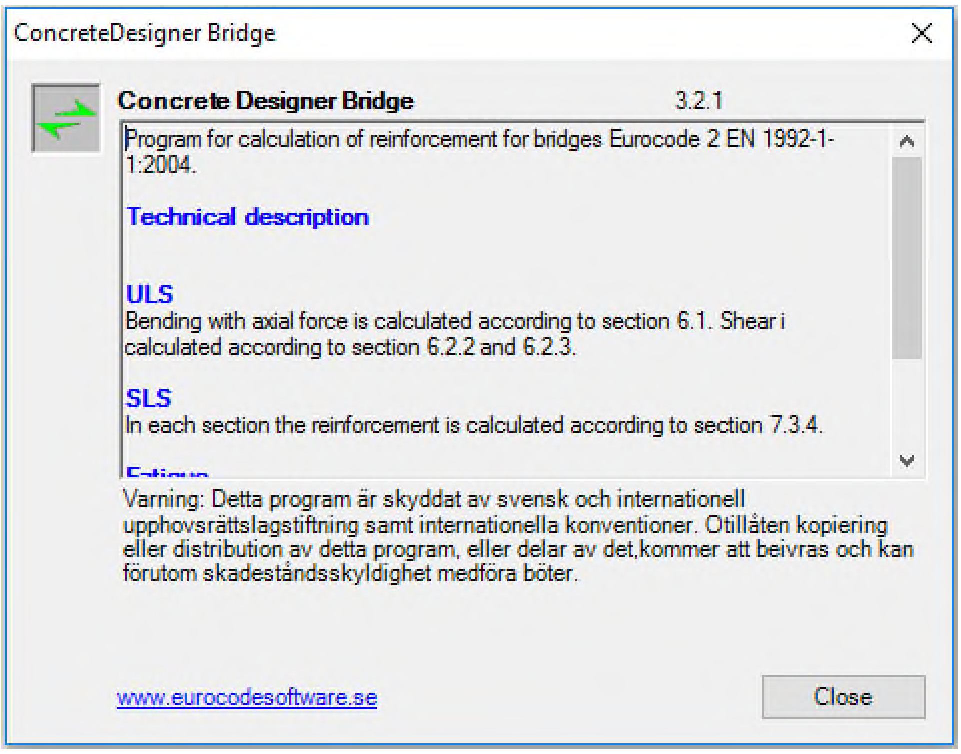


Figure 37 About

7.2 Support

If you get any errors, ideas or questions while using *ConcreteDesign Bridge* you can send a message to Eurocode software AB. To receive a quicker, and better, response please attaches your input file and write down your email address.

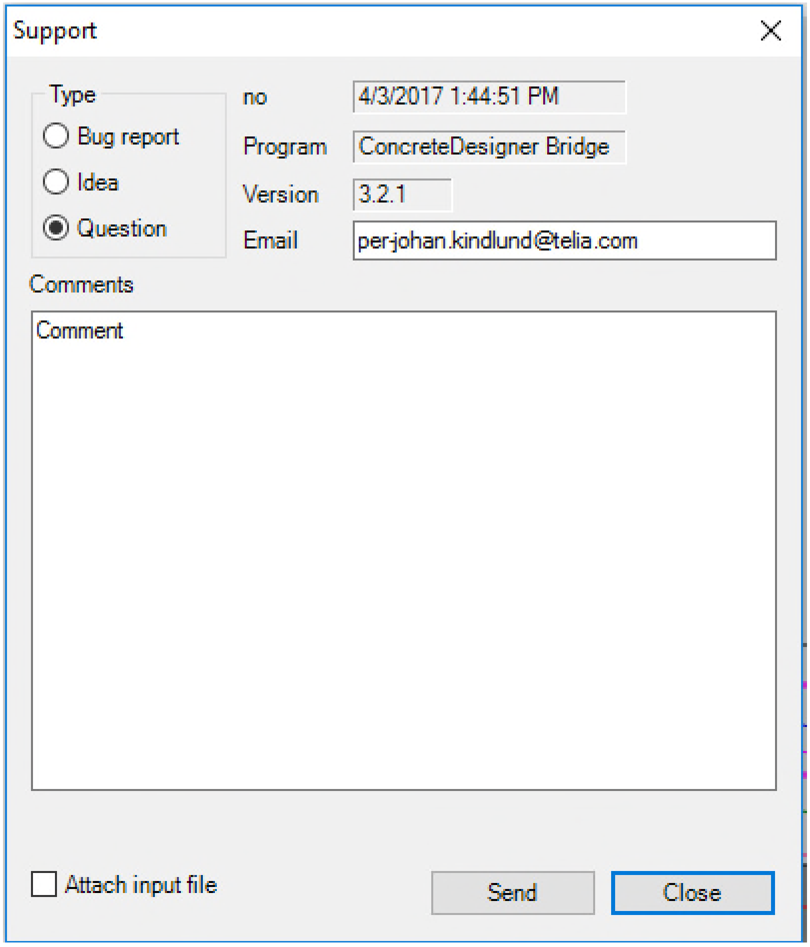
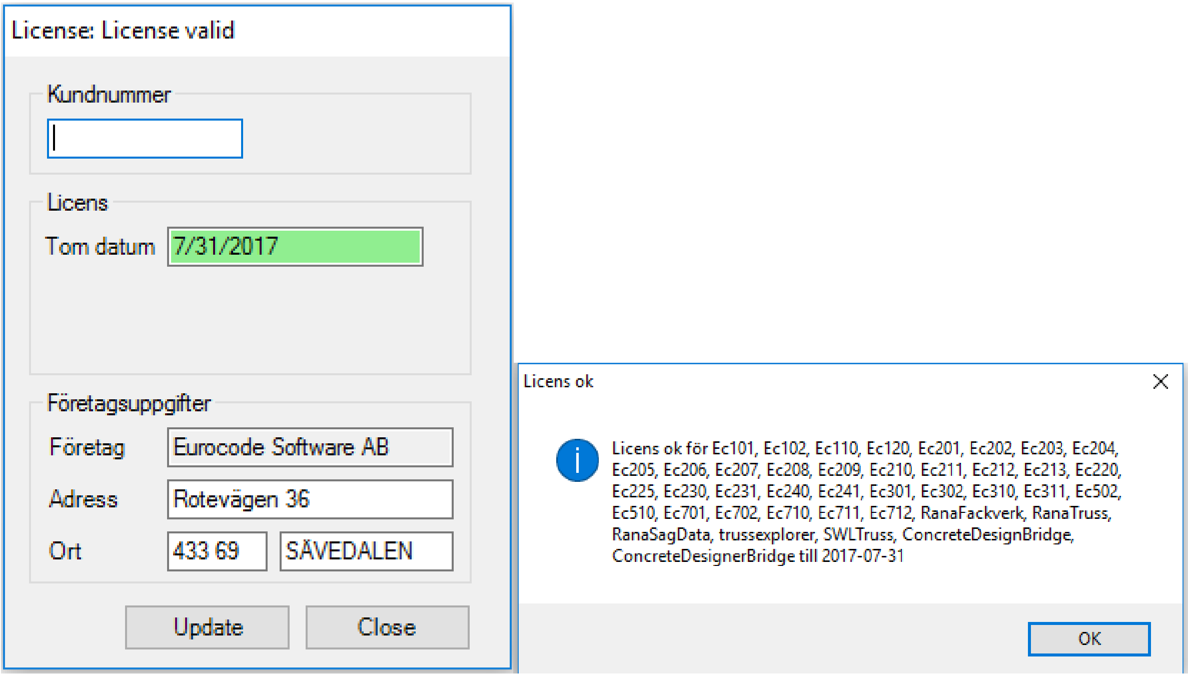


Figure 38 Support

7.3 License

It is simple to update your license, the only thing you need do is to fills in your valid customer number and click the *Update* button. The program will inform which program you have access to. For the customer who want it to update a new a valid date by clicking the button *Control*.



8 How to read the report

A report is created under the tab *Results,* choose *Report.* In the report material properties, sectional forces and required reinforcement is presented. The different parts of the result are shown below. The notations used are explained in each section.

8.1 Notations used for material properties an sectional forces

Ec	Modulus of elasticity of concrete
fcc	Design value of concrete compressive strength
fct	Design value of concrete tensile strength
fst, fsc	Design value of reinforcement strength
fctk0,05	Characteristic value of concrete tensile strength
ecu	ultimate compressive strain in concrete
Ecm	mean value of modulus of elasticity of concrete
fcm	Mean value of concrete compressive strength
fi	diameter
c	input concrete cover
c1	Minimum concrete cover
co	Least free distance between parallel bars in different layers
cs	Least free distance between parallel bars in one layer
Fieff	effective creep
Fakt	factor used in fatigue calculations, EN 1992-2 NN.2.1 (101)
NEd	Design value of applied axial force
MEd	Design value of applied bending moment
VEd	Design value of applied shear force
bw	width of web
bf	width of flange
h	total height
t	thickness of flange
ts	inclined length
nexc	eccentricity of axial force, given form the top of the section, positive upwards
xkrd	x-coordinate

8.2 Longitudinal reinforcement

Required reinforcement amount is calculated in ULS and SLS. The applied reinforcement, denoted as *Actual* in the dialogue, is also presented in a table.

```
Parameters ____________________________________________________________


Max crack width top............................... 0.20 mm

Max crack width bottom............................ 0.20 mm

Crack control factor top.......................... 1.50

Crack control factor bottom....................... 1.50

Number of cycles..................................  1000*10^3



ULS, Calculated longitudinal reinforcement ___________________________

Line Sec  d,t  as,t layers,top....... d,b   as,b layers,bot....

 no   no   mm    mm2  mm  mm  mm  mm   mm    mm2  mm  mm  mm  mm


SLS, Calculated longitudinal reinforcement ___________________________

Line Sec  d,t  as,t layers,top....... d,b   as,b layers,bot....
```

```
          no   no    mm     mm2   mm   mm   mm   mm    mm     mm2   mm   mm   mm   mm
```

Line Line concerned along or across the FE-model.
Section Concerned section
d,t Effective height, top
as,t Reinforcement area, top
layers, top Spacing in each layer, top. First column shows spacing in first layer etc.
d, b Effective height, and bottom.
as,b Reinforcement area, bottom
layers, bot spacing in each layer, bottom

8.3 Shear reinforcement

Required reinforcement with regard to shear force in ULS.

```
ULS, Calculated shear reinforcement (Ec2 6.2.2 & 6.2.3) ──────────────

Lin Sec    VEd   VRd,c   VRi   VRd,s fi Alpha Teta Asw   legs  Spacing
e    no     kN     kN     kN     kN   mm            mm2/m  pc     mm
```

Line Concerned line, along or across the FE-model.
Section Concerned section
VEd Design value of applied shear force
VRd,c Shear resistance of concrete.
VR,i Shear resistance of concrete
VRd,s Shear resistance of reinforcement
fi diameter
Alpha Stirrup inclination.
Teta Strut inclination.
Asw Area of stirrups.
Legs Number of legs/stirrup.
Spacing spacing

8.4 Crack control and crack width

In serviceability limit state the control is done for the actual cross-section, both tensile and compressive reinforcement is considered. A control of cracking is made and crack widths are calculated. The crack widths are calculated in the centre of gravity of the outermost layer of reinforcement.

```
Stress limitations (Ec2 7.2 ) ────────────────────────────────────────

SLS Crack control min curve ──────────────────────────────────────────
SLS Crack control max curve ──────────────────────────────────────────

Line Sect std   z    aid   iid    Sigma,cc Sigma,ct Sigma,st
 no   no        m     m2    m4       MPa      MPa      MPa

Crack width calculation (Ec2 7.3.4) ──────────────────────────────────

SLS min curve ────────────────────────────────────────────────────────
SLS max curve ────────────────────────────────────────────────────────
```

```
Line  Sect    kt     Srm     Msr   Sigma,st  esm-ecm    wk
 no    no             mm     kNm     MPa     promille   mm
```

Line	Concerned line along or across the FE-model.
Section	Concerned section.
std	state
z	height of compressive zone
aid	area of effective cross-section
iid	second moment of inertia of the effective cross-section
Sigma,cc	compressive stress in concrete
Sigma,ct	tensile stress in concrete
Sigma,st	steel stress
kt	loading factor according to Ec2 7.3.4 (2)
Srm	mean cracking distance.
Msr	cracking moment
esm-ecm	strain difference between steel and concrete
wk	characteristic cracking distance

8.5 Fatigue bending reinforcement and concrete

In fatigue the control is made for the real cross-section, that is, both applied tensile and compressive reinforcement are considered. Bending caused by fatigue is calculated for both reinforcement and concrete.

```
Fatigue reinforcment bending, (Ec2 NN.101/NN.106) ────────────────────


Lambda,s,span.........................................   0.64
Lambda,s,support......................................   0.75
Delta Sigma,s,equ top, expression (Ec2 6.71)........... 141.3
Delta Sigma,s,equ bottom, expression (Ec2 6.71)........ 141.3
Delta Sigma,s..........................................dst


               Steel top........ Steel bottom.......
Line  Sect     Sst    Sst    dst    Sst    Sst    dst
 no    no      MPa    MPa    MPa    MPa    MPa    MPa


Fatigue bending concrete (Ec2 6.8.7) ─────────────────────────────────


k1=Sigmac/fcd,fat / k2=0,5+0,45*Sigmac,min/fcd,fat (Ec2 6.77)
Lambda,c...............................................   1.0
fcd,fat expression (Ec2 6.76)..........................  19.0
           Sigma,cc,top........... Sicma,cc,bottom....
Line  Sect   min   max   k1  k2    min   max  k1   k2
 no    no    MPa   MPa             MPa   MPa
```

Line	Concerned line, along or across the FE-model.
Section	Concerned section.
Sst	steel stress
dst	damage equivalent stress range, Ec2 equ NN.101
Sigma,cc	compressive stress, concrete
k1	constant for fatigue, found according to Ec2 6.8.7
k2	constant for fatigue

ue, found according to Ec2 6.8.7

8.6 Fatigue shear

Also, a control of shear due to fatigue is performed. Equation 6.77 in Ec2 section 6.8.7 is used when there is no shear reinforcement, otherwise equations 6.78 and 6.79 are used.

```
Fatigue bending shear, expression (Ec2 6.77 or 6.78 & 6.79) ──────────


k1=Sigmac/fcd,fat / k2=0,5+0,45*Sigmac,min/fcd,fat

k1=VEd/VRd,c / k2=0,5+0,45*VEd/VRd,c

fcd,fat................................................  9.0

DeltaSigmaRsk.......................................... 141.3


                 Sigmac / VEd/VRd,c..... Sigmasw.............

Line  Sec   teta   Min    Max   k1  k2     Min    Max  Delta

 nr    nr          MPa    MPa              MPa    Mpa    Mpa
```

Line	Concerned line, along or across FE-model
Section	Concerned section
Teta	Inclination of strut.
Sigmac	Concrete stress
Sigmasw	Steel stress, stirrups
k1	given by Ec2 6.8.7 equ. 6.77 or equ. 6.78 and 6.79 depending on if there are shear reinforcement
k2	given by Ec2 6.8.7 equ. 6.77 or equ. 6.78 and 6.79 depending on if there are shear reinforcement