



# Tutorial

The Reinforcement Module

## Preface

The purpose of this tutorial is to learn how to use and understand the reinforcement module to calculate the section forces used for design of reinforcement. How to use the functions in the **Visualization** module related to the **Reinforcement** module will also be presented.

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# 1 Overview

This tutorial will guide you through the steps required to create reinforcement output. Functions related to reinforcement output in post-processing will also be shown. The tutorial is based on a slab spanning in both directions with fixed support on all sides, see Figure 1-1. The theory behind this module is found in chapter 21 in the BRIGADE/Plus user manual.

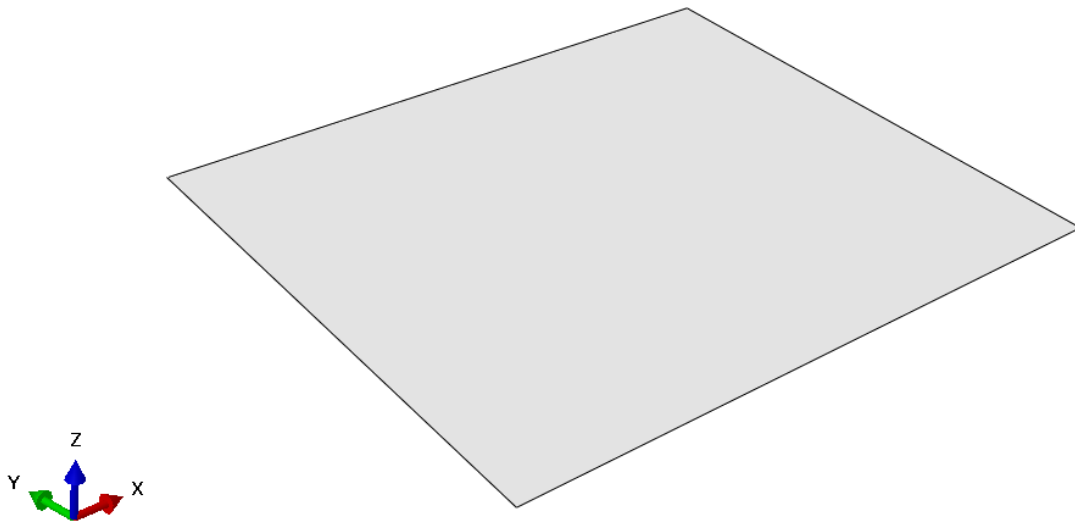


Figure 1-1 Slab spanning in both directions with fixed support on all sides.

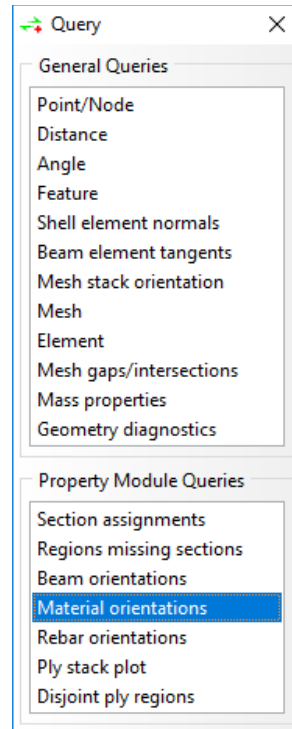
## 2 How to create Reinforcement Output

In BRIGADE/Plus it is possible calculate the section forces used for design of reinforcement in slabs in accordance with the Wood-Armer method. Follow the steps outlined below to create such reinforcement output.

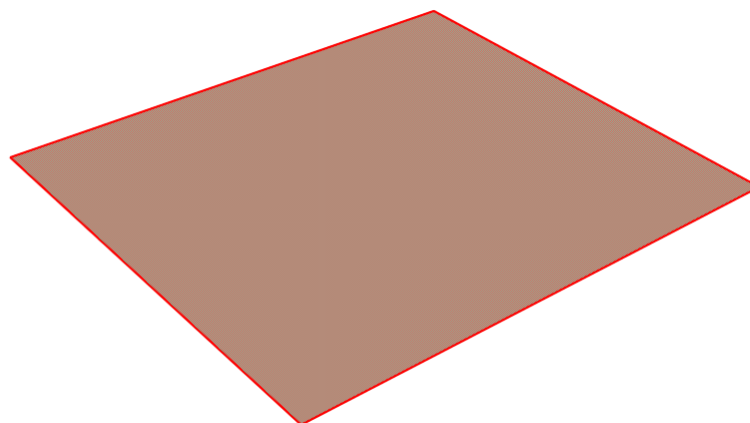
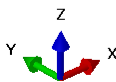
1. To make sure the reinforcement angle is defined correctly check the material orientation in the model. Switch to the **Property** module and click the **Query Information** icon



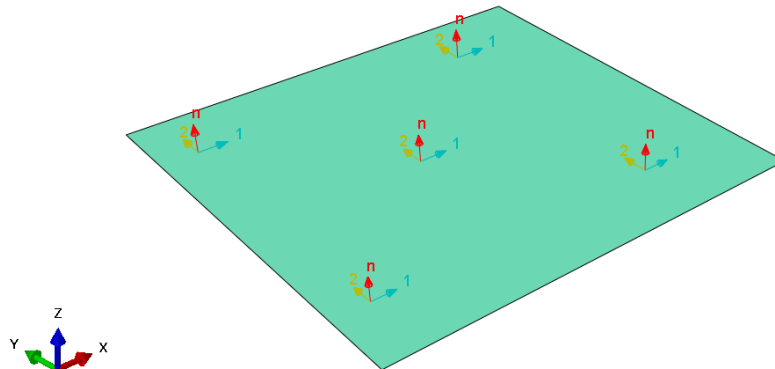
or from the main menu, select **Tools** → **Query**. The **Query** window appears.



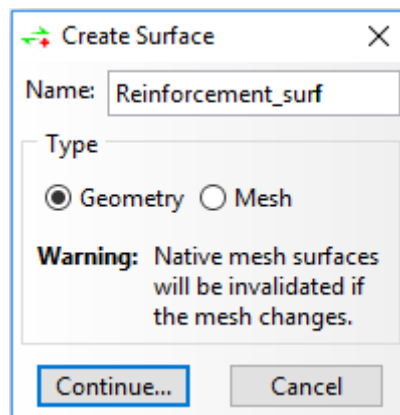
2. From the list **Property Module Queries**, select **Material orientations**.
3. Select the surface which is going to be used for the **Reinforcement Output**.



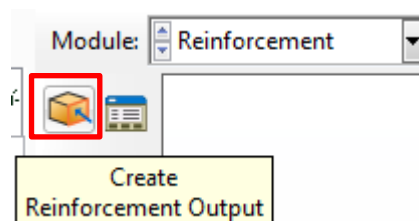
- Press **Done** in the prompt area. Material orientations for the selected area are now shown in the model.



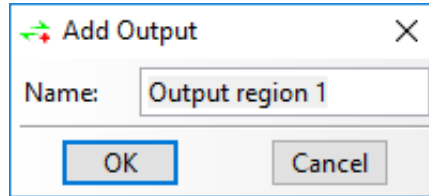
- Create a surface to be used as **Reinforcement Output** by switching to the **Assembly** module and pressing **Tools** → **Surface** → **Create**. Name the surface **Reinforcement\_surf**. Press **Continue**.



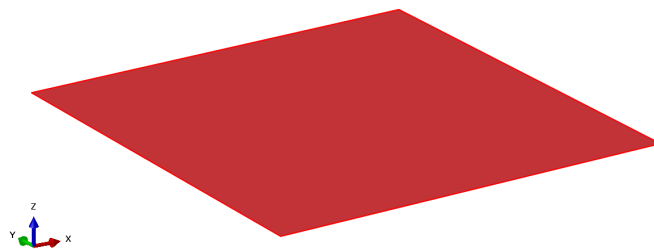
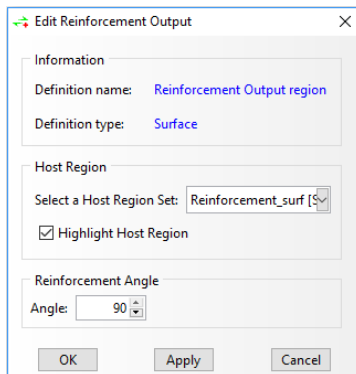
- Select the surface which is going to be used for the **Reinforcement Output**. Press **Done** in the prompt area. Which side of the shell to act as the surface does not matter, hence either **Brown**, **Purple** or **Both sides** can be selected.
- To create a **Reinforcement Output** the previously created surface needs to be selected as the reinforcement output area. Switch to the **Reinforcement** module, press the **Create Reinforcement Output** icon or from the main menu select **Reinforcement** → **Create Output**. The **Add Output** dialog opens.



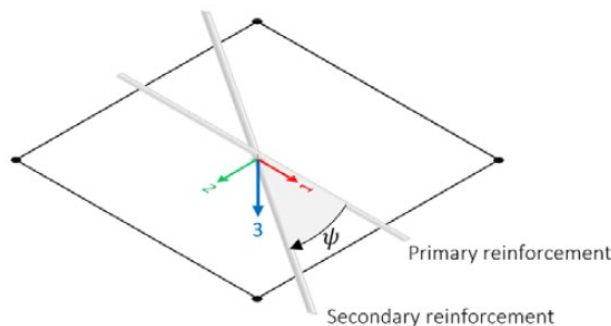
- Name your region **Output region 1** and press **OK**.



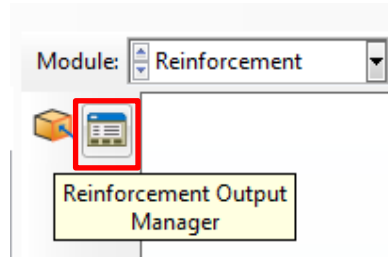
9. The **Edit Reinforcement Output** window will appear. Select **Reinforcement\_Surf** as the **Host Region Set**. Check the **Highlight Host Region** box to visualize the region. The **Reinforcement Angle** is set to 90 degrees.



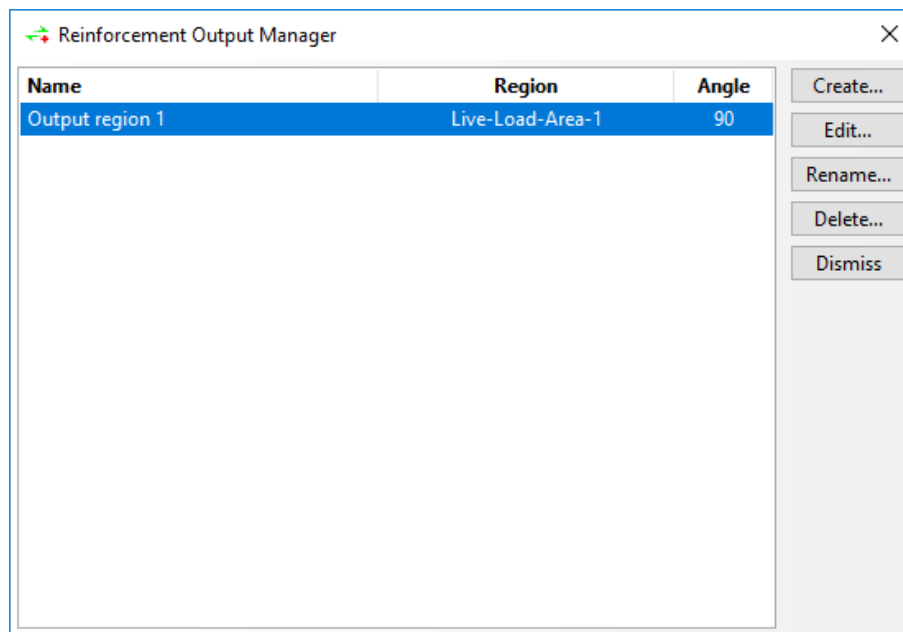
**Note:** The **Reinforcement Angle** can only be chosen between -90 and 90 degrees. The primary reinforcement direction is defined as the 1-direction of the material orientation for the selected section. The secondary reinforcement direction is defined by specifying the reinforcement angle,  $\psi$ . Positive values indicates a positive rotation around the shell elements normal according to the material orientation. See figure below



10. Press **OK** to close the window.
11. Click the **Reinforcement Output Manager** icon or from the main menu select **Reinforcement → Output Manager**. The **Reinforcement Output Manager** dialog opens.



12. All created Reinforcement Output is shown in this dialogue. You can use the dialogue to **Create, Edit, Rename** and **Delete** Reinforcement Output.



13. Press **Dismiss** to close the window.
14. Switch to the **Job** module and run an analysis with the previously created input.

**NOTE:** When an analysis is submitted using the above input, section forces used for design of reinforcement will be calculated automatically. However, in order for calculations to be performed the section forces **SF** and **SM** needs to be requested.



### 3 Visualization

When opening an ODB-file in the **Visualization** module containing **Reinforcement Output**, section forces used for design of reinforcement will be available for selection among the result output variables. The forces available for selection depends on if a Basic Load Case / Traffic Load Case or Load Combination / Load Group is investigated. In Table 3-1, a summary of all components used for the design of reinforcement and for which cases they are available are presented. For more information regarding the components and how they are calculated, see section 21 in the BRIGADE/Plus user's manual.

Table 3-1 Components for the design of reinforcement

Variable	Component	Description	Basic Load Cases / Traffic Load Cases	Load Combinations / Load Groups
MR	MR1	Moment used for design in the primary reinforcement direction		√
	MR2	Moment used for design in the secondary reinforcement direction		√
	MR3	"Dummy"-component not used for design of reinforcement		√
NR	NR1	Normal force used for design in the primary reinforcement direction		√
	NR2	Normal force used for design in the secondary reinforcement direction		√
	NR3	"Dummy"-component not used for design of reinforcement		√
PRINCIPALM	DELTA	Angle between the primary reinforcement direction and principal moment direction 1	√	
	M1	Principal moment direction 1	√	
	M2	Principal moment direction 2	√	
PRINCIPALN	DELTA	Angle between the primary reinforcement direction and principal normal force direction 1	√	
	N1	Principal normal force direction 1	√	
	N2	Principal normal force direction 2	√	
MRALTA	MRALTA11	Design moment for alternative A in the primary reinforcement direction	√	√
	MRALTA22	Design moment for alternative A in the secondary reinforcement direction	√	√
	MRALTA12	"Dummy"-component not used for design of reinforcement	√	√
MRALTB	MRALTB11	Design moment for alternative B in the primary reinforcement direction	√	√
	MRALTB22	Design moment for alternative B in the secondary reinforcement direction	√	√
	MRALTB12	"Dummy"-component not used for design of reinforcement	√	√
NRALTA	NRALTA11	Design normal force for alternative A in the primary reinforcement direction	√	√
	NRALTA22	Design normal force for alternative A in the secondary reinforcement direction	√	√
	NRALTA12	"Dummy"-component not used for design of reinforcement direction	√	√
NRALTB	NRALTB11	Design normal force for alternative B in the primary reinforcement	√	√
	NRALTB22	Design normal force for alternative B in the secondary reinforcement direction	√	√
	NRALTB12	"Dummy"-component not used for design of reinforcement	√	√

**NOTE:** **MR1** and **MR2** are results depending on **MRALTA** and **MRALTB** while **NR1** and **NR2** are results depending on **NRALTA** and **NRALTB**. The section forces used for design of reinforcement are calculated by creating envelopes of alternative A and B which is the reason why these can only be found in **Load Groups** and **Load Combinations**. See below how they are calculated

$MR1_{max} = \max[MRALTA11, MRALTB11]$	$NR1_{max} = \max[NRALTA11, NRALTB11]$
$MR1_{min} = \min[MRALTA11, MRALTB11]$	$NR1_{min} = \min[NRALTA11, NRALTB11]$
$MR2_{max} = \max[MRALTA22, MRALTB22]$	$NR2_{max} = \max[NRALTA22, NRALTB22]$
$MR2_{min} = \min[MRALTA22, MRALTB22]$	$NR2_{min} = \min[NRALTA22, NRALTB22]$

To better understand the section forces used for design of reinforcement, the procedure from basic section moments to design moments are evaluated below. The investigation is carried out in the primary reinforcement direction by creating a path running along the global X-direction close to the slab edge. The section moments required for the calculation, i.e. **SM1** and **SM3**, for deadweight loading along the path are shown in Figure 3-1.

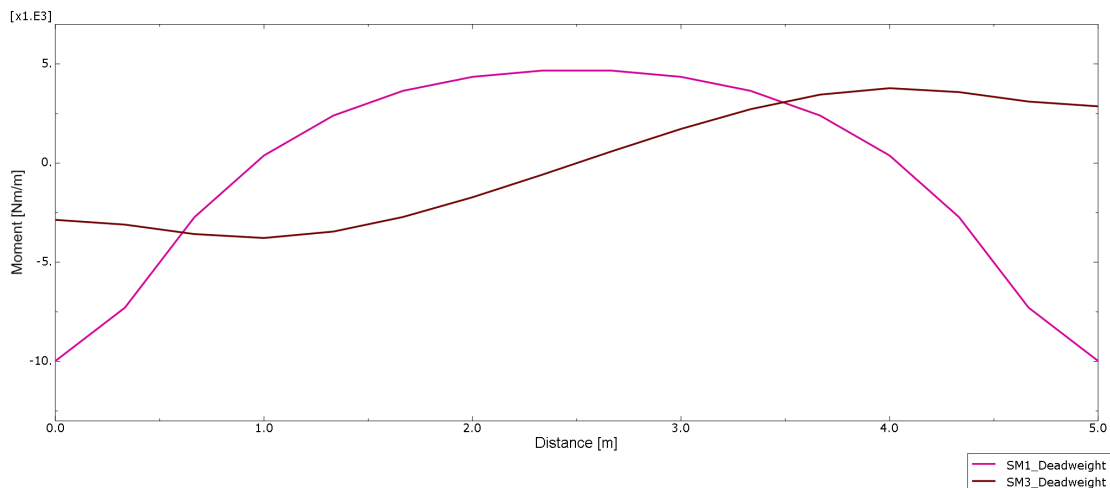


Figure 3-1 *SM1, SM3 for deadweight along a path running in the global X-direction close to the slab edge.*

For the current example, when the angle between the primary and the secondary reinforcement direction is 90°, the equations for calculating alternative A and B of the section moments used for design of reinforcement in the primary reinforcement direction is reduced to the equations below. See section 21 in the BRIGADE/Plus user's manual for the original equations.

$$MRALTA11 = SM1 + SM3$$

$$MRALTB11 = SM1 - SM3$$

As seen in Figure 3-1, the sign of the twisting moment, **SM3**, is negative on the left-hand side of the deck and positive on the right-hand side. According to the above equations **MRALTA11** will therefore provide the minimum value on the left-hand side and maximum value on the right-hand side. **MRALTB11** on the other hand will produce opposite results. This can be seen in Figure 3-2 where **MRALTA11** and **MRALTB11** are shown together with **SM1** and **SM3**. The section moments used for design of the primary reinforcement are further

emphasized in Figure 3-3 where the maximum- and minimum values of **MR1** are shown together with **MRALTA11** and **MRALTB11**. Here it can be clearly seen that the maximum and minimum values of the designing moments originate from one of the A- and B-alternative on one side of the deck and the other alternative on the other side.

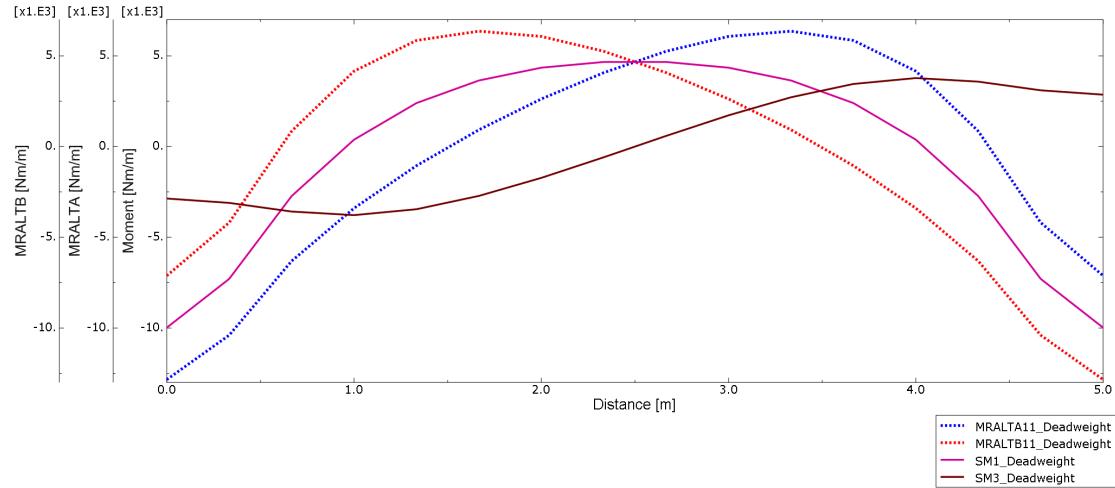


Figure 3-2 *SM1, SM3, MRALTA11 and MRALTB11 for deadweight along a path running in the global X-direction close to the slab edge.*

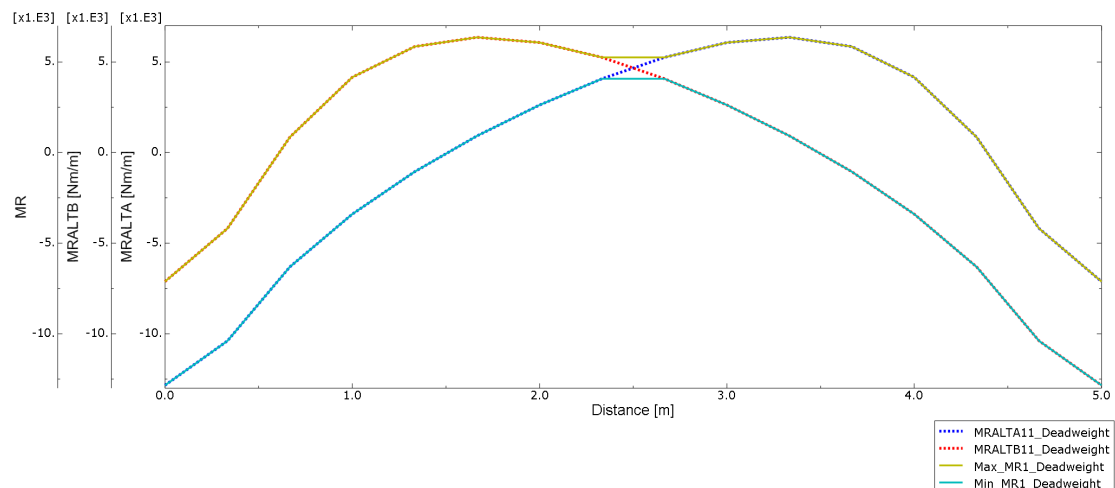


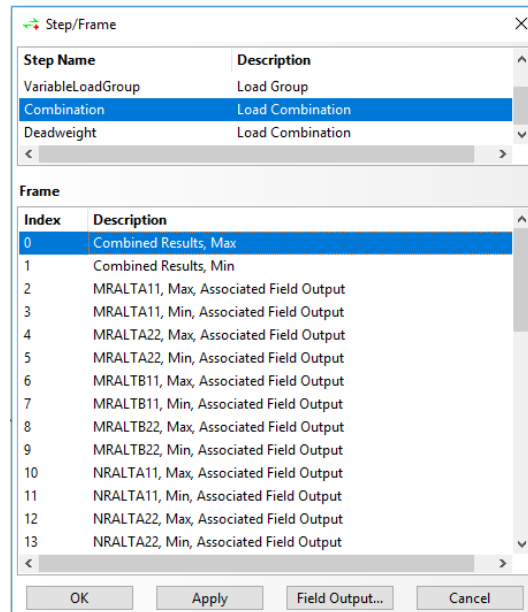
Figure 3-3 *MRALTA11, MRALTB11, Max MR1 and Min MR1 for deadweight along a path running in the global X-direction close to the slab edge.*

In the above figures it can also be noted that the section moment to be used for design of reinforcement can be significantly larger than the basic section moment without considering the impact of the twisting moment as well. It can also be noted that the most adverse response is not necessarily obtained in the same location as if only the basic section moment was to be considered.

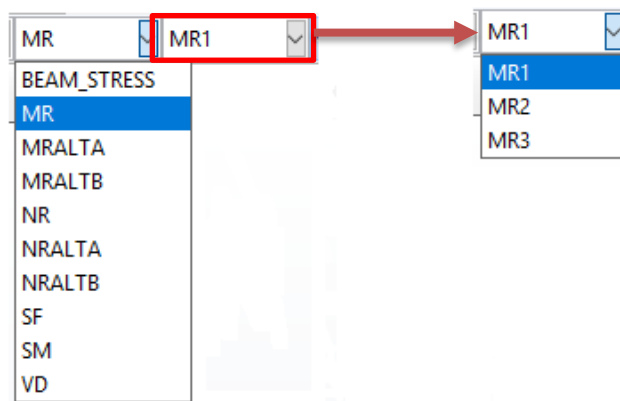
## 4 Load History

In more complex scenarios it might not be obvious which alternative produce the maximum and minimum response. To find the section force used for design of reinforcement in a specific element follow the steps below.

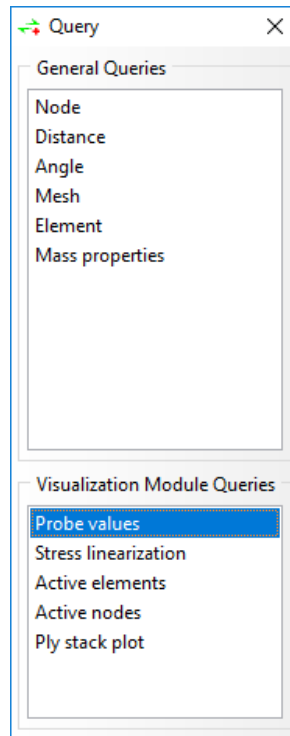
- From the main menu select **Results** → **Step/Frame**. The **Step/Frame** dialog opens. Select **Combination** under **Step Name** and **Frame 0 Combined Results, Max**.



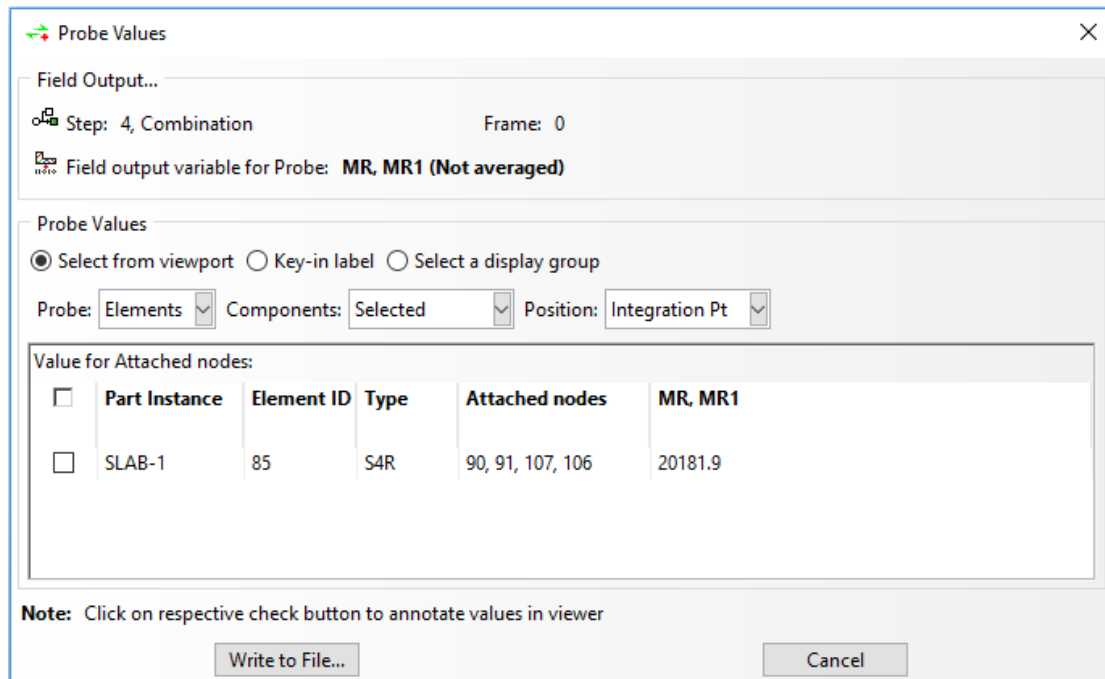
- In the **Visualization** module, pick the design moment or normal force and the primary or secondary reinforcement direction. For this example the design moment **MR** in the primary reinforcement direction **MR1** is chosen.



- Click the **Query Information** icon  or from the main menu, select **Tools** → **Query**. The **Query** dialog opens.



4. Select **Probe values** under **Visualization Module Queries**. The **Probe Values** dialog opens.
5. Select the element for which a load history is to be extracted. Values for the selected elements will be shown in the **Probe Values** dialog.

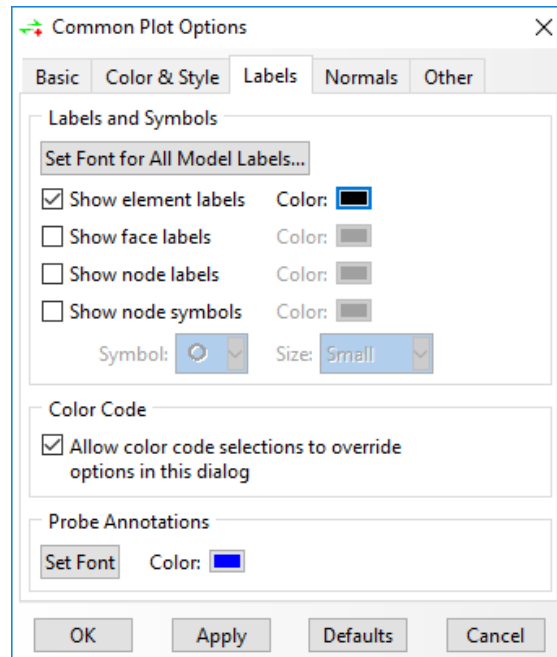


- To find out if the section force used for design of reinforcement is **MRALTA** or **MRALTB** value the Load History needs to be requested for each of these components in the element.

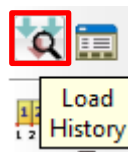
### INFO

For an easier approach to find the same element in the Load History, use the function: **Show element labels**.

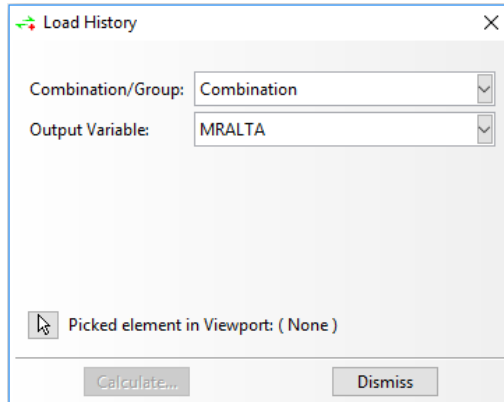
Select **Options** → **Common**. Select **Labels** and check the box for **Show element labels**.



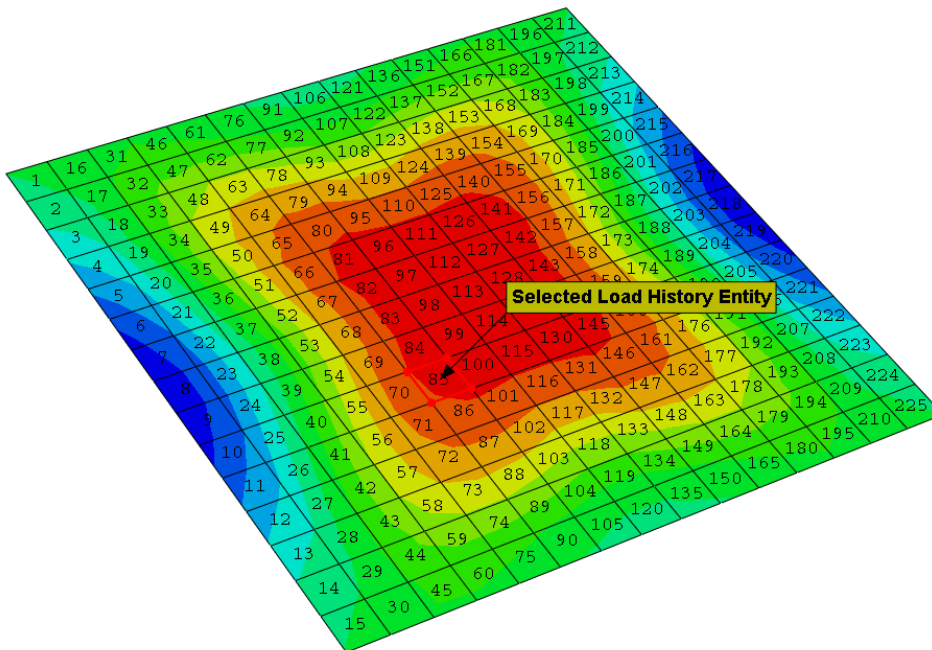
- Press the **Load History** icon.



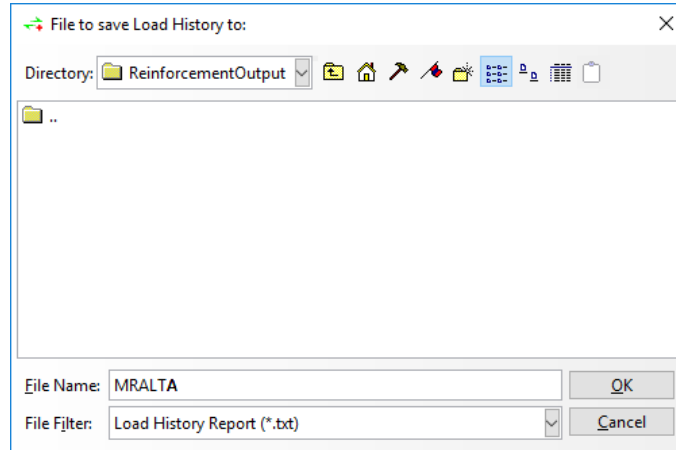
- The **Load History** dialog opens.



9. Press  to pick an entity in the viewport. Select the same element as previously.



10. Press **Calculate...** The **File to save Load History to** dialog opens. Name the file **MRALTA** for the Load History report and where to save it. Press **OK**.



11. A Load History Report will be generated and presented in a txt-file.
12. Repeat step 8 and 10 but choose **Output Variable MRALTB** instead to generate a Load History Report for **MRALTB**. Name the file **MRALTB**.
13. Compare the results for **MRALTA11** and **MRALTB11** to find out which one that corresponds to the **MR1** value found using **Probe Values**. The corresponding load history is the load history for **MR1**. For this example, **MRALTB11** became the corresponding load history for **MR1**.

Maximum Envelope:

Results for component: MRALTA11

Combined Load	Type	Char. Value	Scaling	Coefficient	Design Value
DeadWeight (Frame: 1)	Permanent	6750.18	1.00	1.35	9112.74
VariableLoadGroup	Variable	3440.46	1.00	1.50	5160.69
SUMMATION:					14273.43

Maximum Envelope:

Results for component: MRALTB11

Combined Load	Type	Char. Value	Scaling	Coefficient	Design Value
DeadWeight (Frame: 1)	Permanent	9544.41	1.00	1.35	12884.95
VariableLoadGroup	Variable	4864.63	1.00	1.50	7296.95
SUMMATION:					20181.89 ←