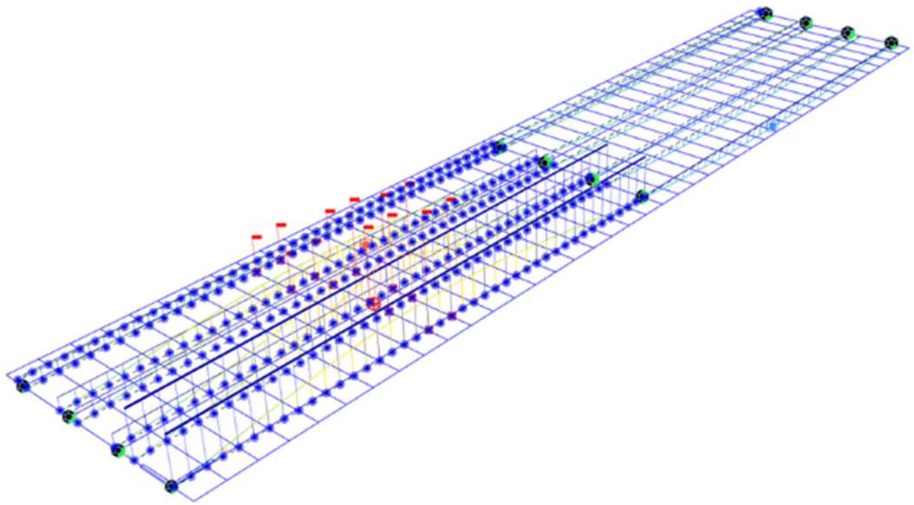
Moving load analysis

(Eurocode 1-2:2003)

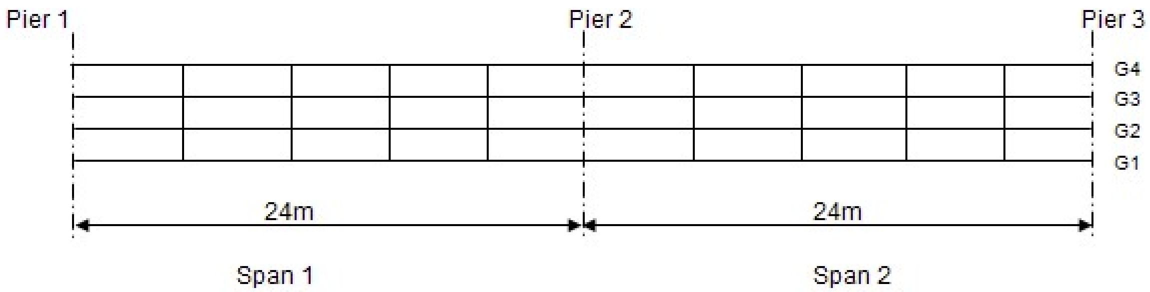


Overview

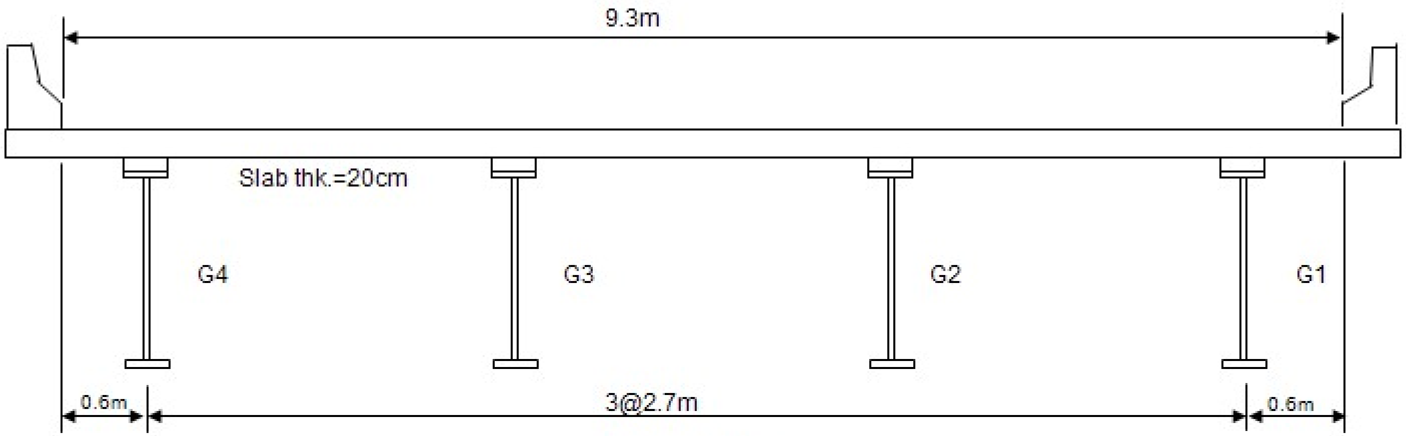
- **Bridge overview**
  - ✓ *2 span continuous composite girder bridge*
  - ✓ *Span length: 2@24 m*
  - ✓ *Carriageway width: 9.3 m*
  - ✓ *Unit system: kN, m*
- **Lane definition**
  - ✓ *Notional lanes & remaining area*
  - ✓ *Location and numbering of the lanes*
- **Vehicle load**
  - ✓ *Load Model 1*
  - ✓ *Load Model 2*
  - ✓ *Load Model 3*
- **Moving load analysis option**
  - ✓ *Concurrent forces*
- **Result evaluation**
  - ✓ *Influence line*
  - ✓ *Moving load tracer*
  - ✓ *Envelope of member forces*

1. Bridge overview

- *Bridge type: Straight bridge*
- *Span length: 2@24 m*
- *Carriageway width: 9.3 m*
- *Spacing of cross beams: 4.8 m*



a) Plan view



b) Cross section

2. Number and width of notional lanes

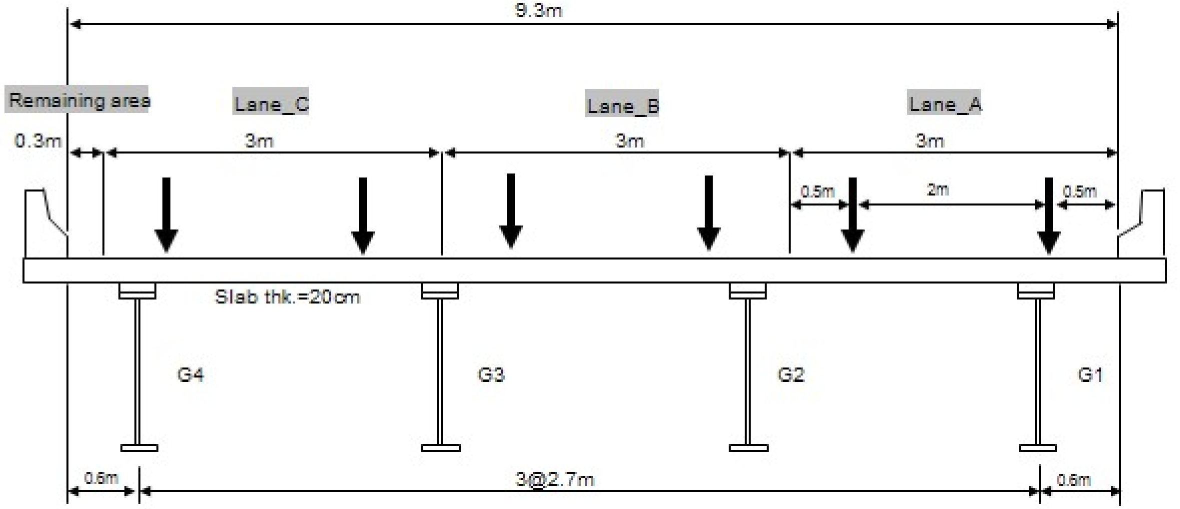
EN 1991-2:2003. Table 4.1 Number and width of notional lanes

Carriageway width w	Number of notional lanes	Width of a notional lane w_l	Width of the remaining area
$w = 9.3\ m$	$n_l = Int(w/3) = 3$	$3\ m$	$w - 3 \times n_l = 0.3\ m$

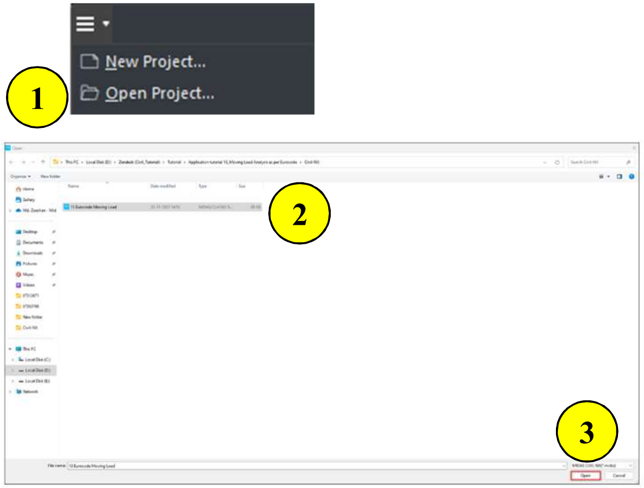
3. Location and numbering of the lanes of the bridge

- ✓ **For each individual verification, the number of lanes to be taken into account as loaded, their locations on the carriageway and their numbering should be so chosen that the effects from the load models are the most adverse. (*EN 1991-2:2003, 4.2.4(2)*)**

- ✓ **In MIDAS CIVIL NX, the user directly defines the locations of lanes, and the numbering of the lanes for design is automatically performed. In this tutorial, the locations of the lanes are shown below.**



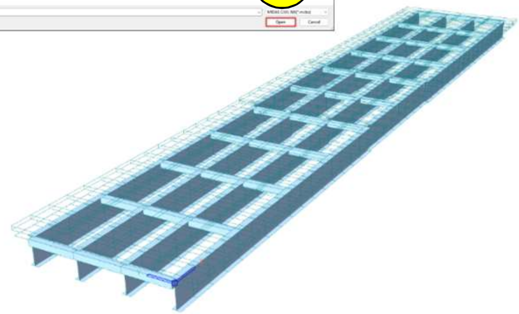
Step 1. Open the model file.



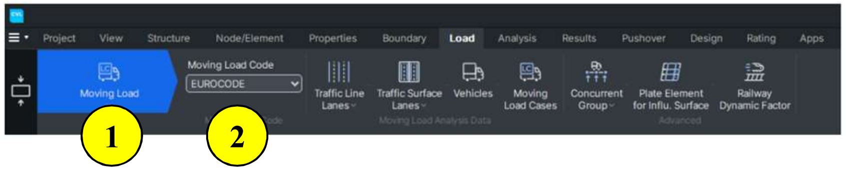
1. **Main Menu > File > Open Project**
2. Select 'Eurocode Moving Load.mcbz'
3. Click **[Open]** button.

This tutorial is intended to introduce the functions of Moving load analysis. Therefore the procedures of creating elements, assigning static loads and boundary conditions are omitted here.

Please refer to the online manual for the detailed usage.



Step2. Define moving load code



1. **Main Menu > [Load] Tab > Moving Load**
2. Moving Load Code: **EUROCODE**

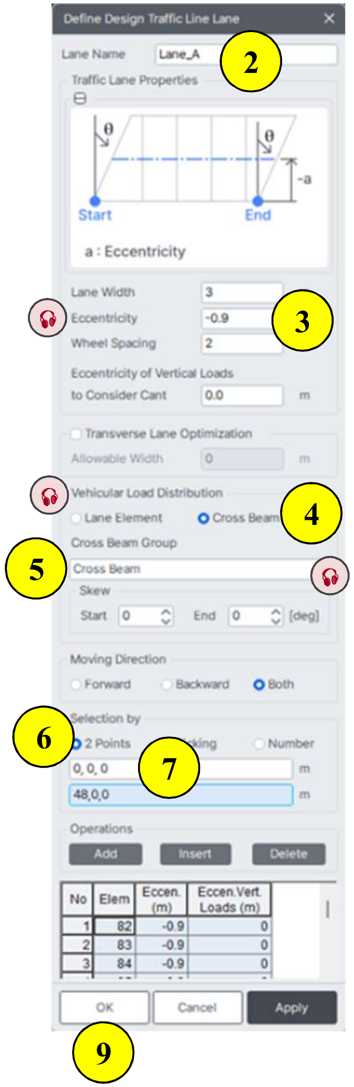
Step3-1. Define traffic line lane (Lane_A)

Depending on the design members, Lane_A could be notional lane No. 1,2 or 3. The number of lanes is determined when performing analysis.

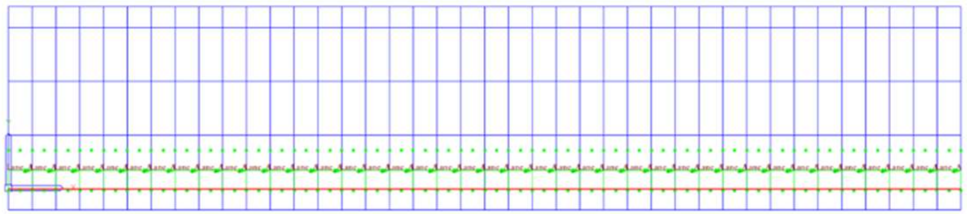
For detail information of Vehicular Load Distribution, refer to the next page.

For the calculation of the eccentricity, refer to the page 7 in this tutorial.

Cross Beam group comprises of all the transverse elements.



1. *Main Menu > [Load] Tab > [Load Type] Group > Moving Load > [Moving Load Analysis Data] Group > Traffic Line Lanes*
2. *Lane Name: **Lane_A***
3. *Eccentricity : **-0.9 m***
4. *Vehicular Load Distribution : **Cross Beam***
5. *Cross Beam Group: **Cross Beam***
6. *Selection by : **2 Points***
7. *Click **(0,0,0).***
8. *Click **(48,0,0).***
9. *Click **[OK]** button.*

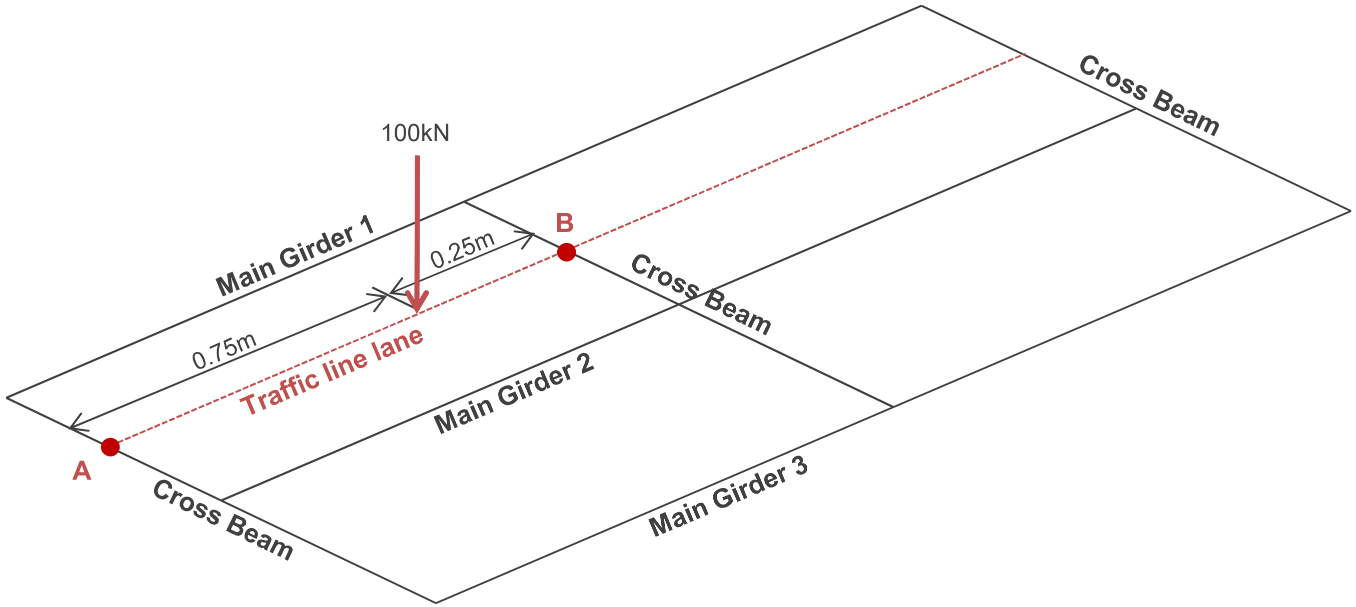


Tip 1. Vehicular load distribution

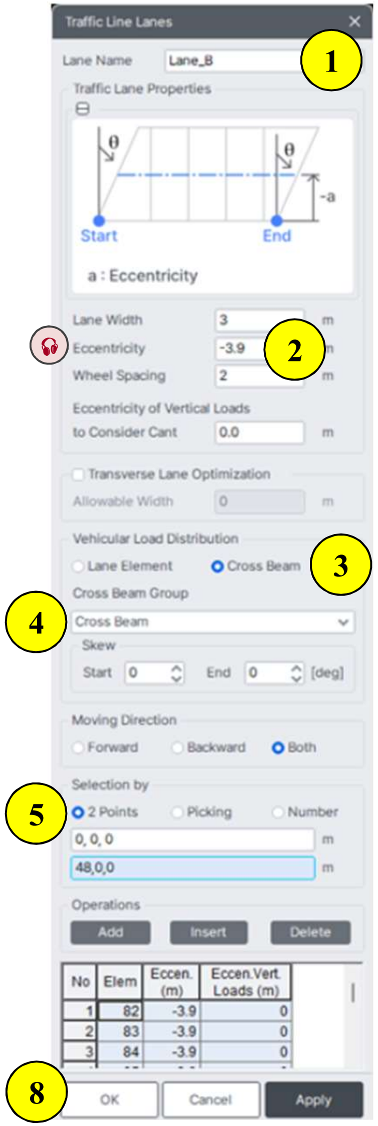
▯ **Lane element**: Apply loads to the traffic line lane elements reflecting the eccentricity.
When defining lanes by the lane element type, the vertical load components (vehicle loads) and the moments due to the eccentricity are assigned only to the line lane elements. Even though the lanes can be located on cross beam elements, if the lane element type is selected, then the distribution of the loads onto the cross beams will not be considered.

▯ **Cross beam**: Apply the traffic loads to the cross beams.
When using Cross Beam type, the eccentricity is used only for locating the lanes from the line lane elements. The vehicle loads are distributed to the girders via cross beam elements defined as a Cross Beam Group. If the user is modeling a bridge having multiple girders, the Cross Beam type is recommended for vehicular load distribution.

For example, an axle load of 100kN is located as shown below. Then, concentrated loads, 25kN and 75kN, are applied to point A and point B respectively. The cross beams themselves are loaded.

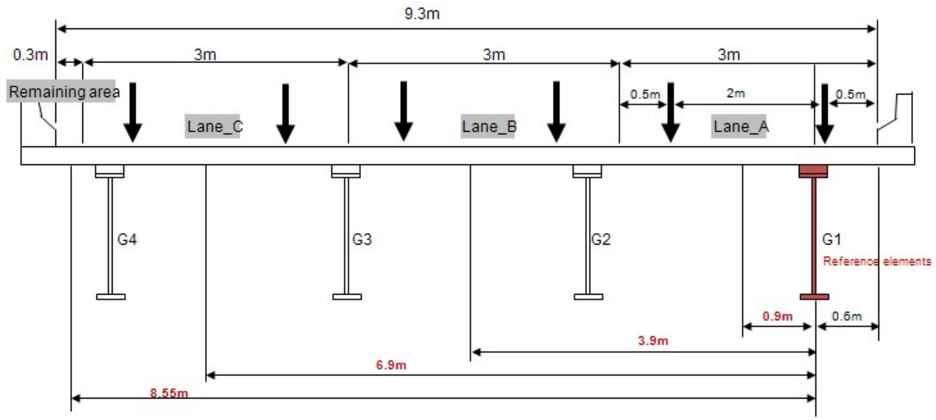


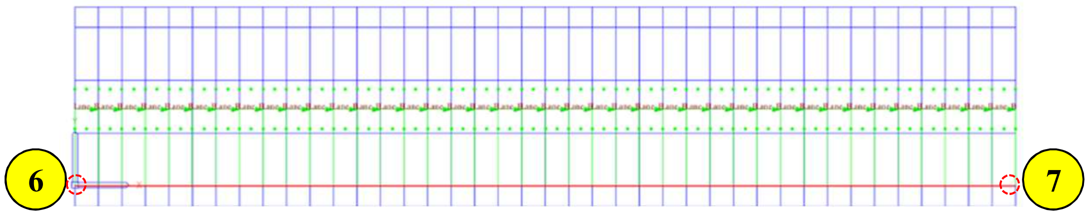
Step3-2. Define traffic line lane (Lane B)



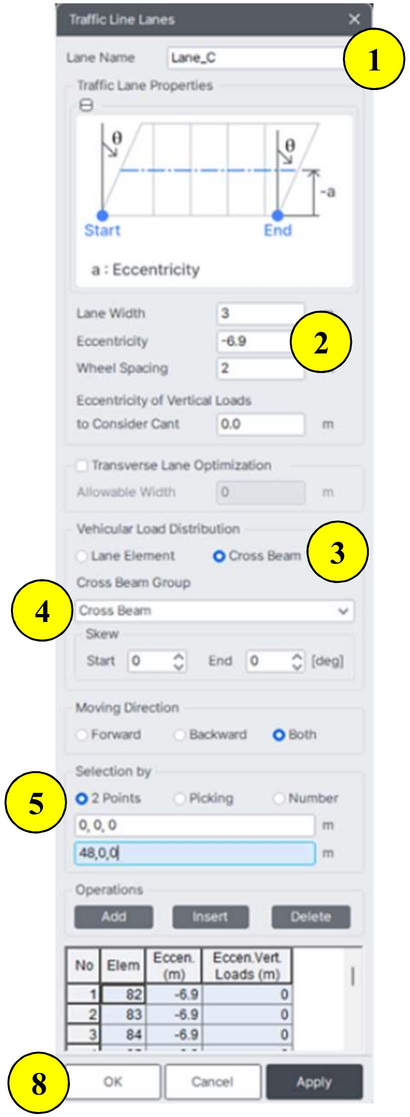
- Enter the eccentricity of a traffic line lane relative to a traffic line lane element. Traffic line lane elements are defined as the reference frame elements from which the eccentricity is measured.
- In this tutorial, the eccentricities are calculated as shown in the right figure.

1. Lane Name: ***Lane_B***
2. Eccentricity : ***-3.9 m***
3. Vehicular Load Distribution : ***Cross Beam***
4. Cross Beam Group: ***Cross Beam***
5. Selection by : ***2 Points***
6. Click ***(0,0,0).***
7. Click ***(48,0,0).***
8. Click **[OK]** button.

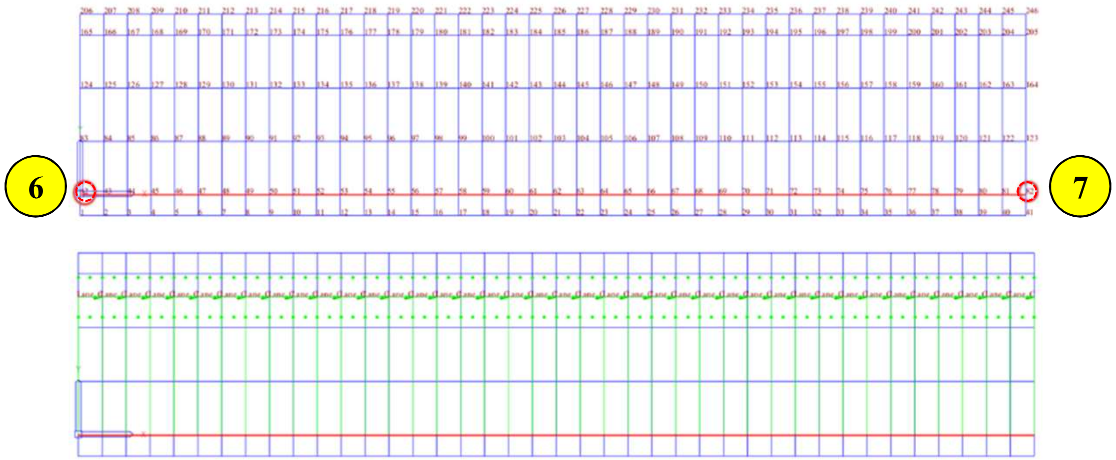




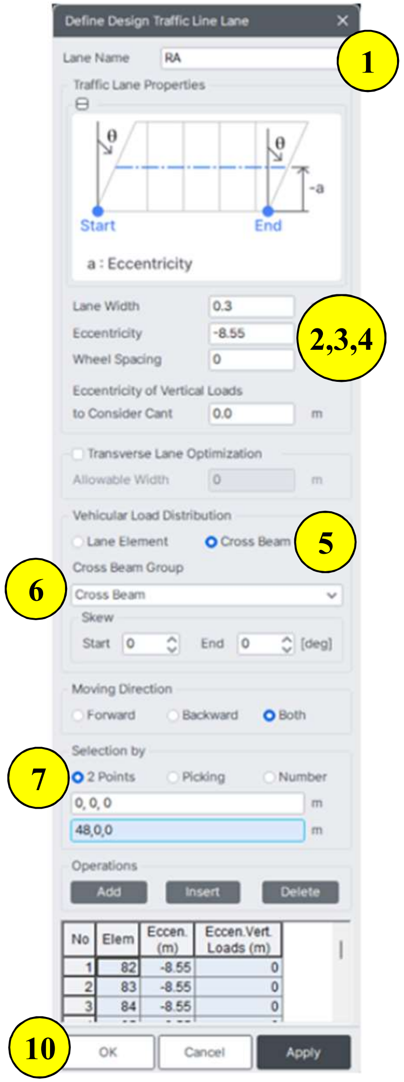
Step3-3. Define traffic line lane (Lane C)



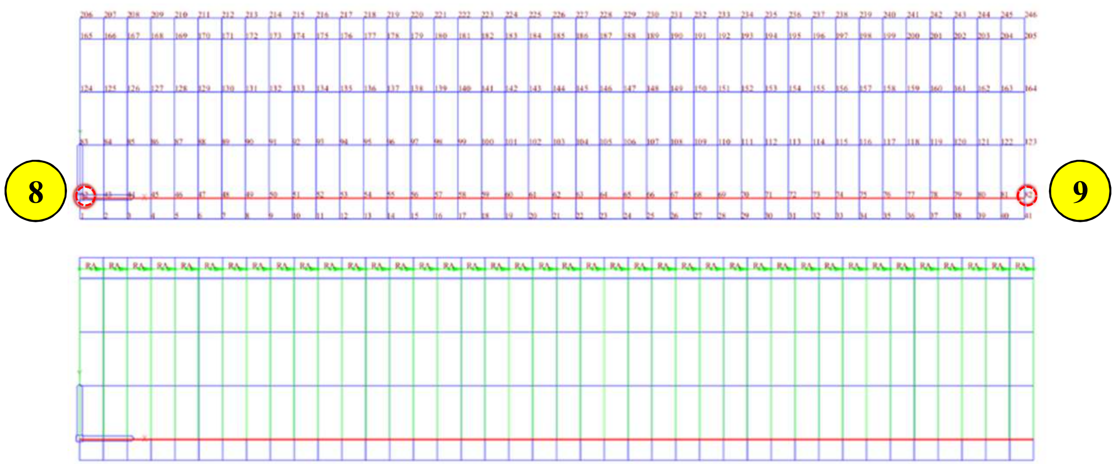
1. Lane Name: ***Lane_C***
2. Eccentricity : ***-6.9 m***
3. Vehicular Load Distribution : ***Cross Beam***
4. Cross Beam Group: ***Cross Beam***
5. Selection by : ***2 Points***
6. Click ***(0,0,0)***
7. Click ***(48,0,0)***
8. Click **[OK]** *button.*



Step3-4. Define remaining area

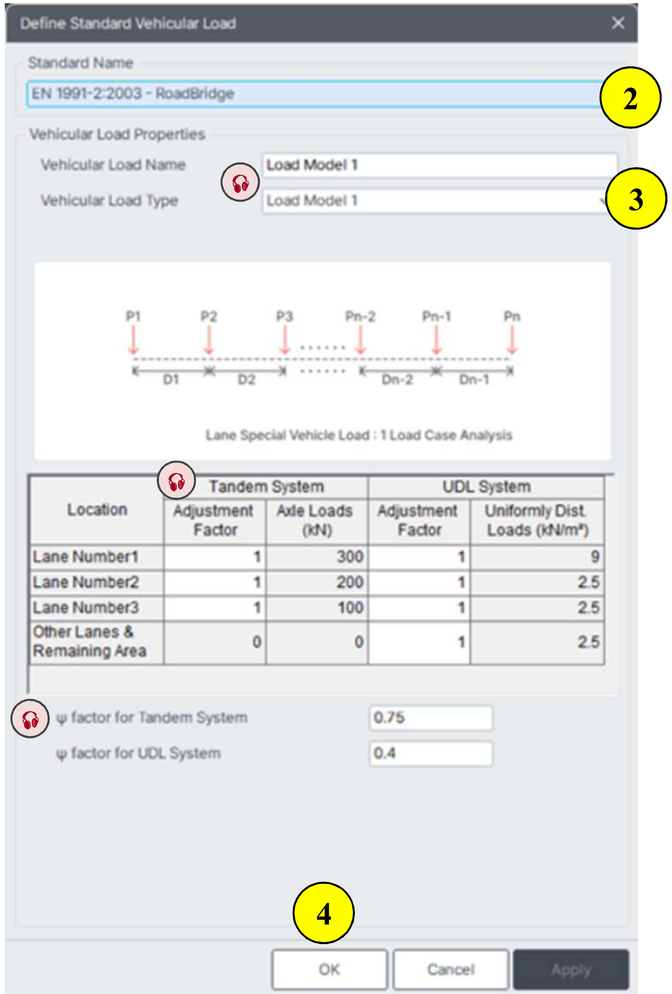


1. Lane Name: ***RA***
2. Eccentricity : ***-8.55 m***
3. Wheel Spacing : ***0 m***
4. Lane Width : ***0.3 m***
5. Vehicular Load Distribution : ***Cross Beam***
6. Cross Beam Group: ***Cross Beam***
7. Selection by : ***2 Points***
8. Click ***(0,0,0)***
9. Click ***(48,0,0)***
10. Click **[OK]** *button.*



Step4. Define vehicular load

(Case 1. Check Load Model 1)



1. *Main Menu > [Load] Tab > [Load Type] Group > Moving Load > [Moving Load Analysis Data] Group > Vehicles > [Add Standard] Button*
2. *Standard Name : **EN 1991-2:2003 – RoadBridge***
3. *Vehicular Load Type : **Load Model 1***
4. *Click* **[OK]** *button.*

Load Model 1 (LM1) : Concentrated and uniformly distributed loads, which cover most of the effects of the traffic of lorries and cars.

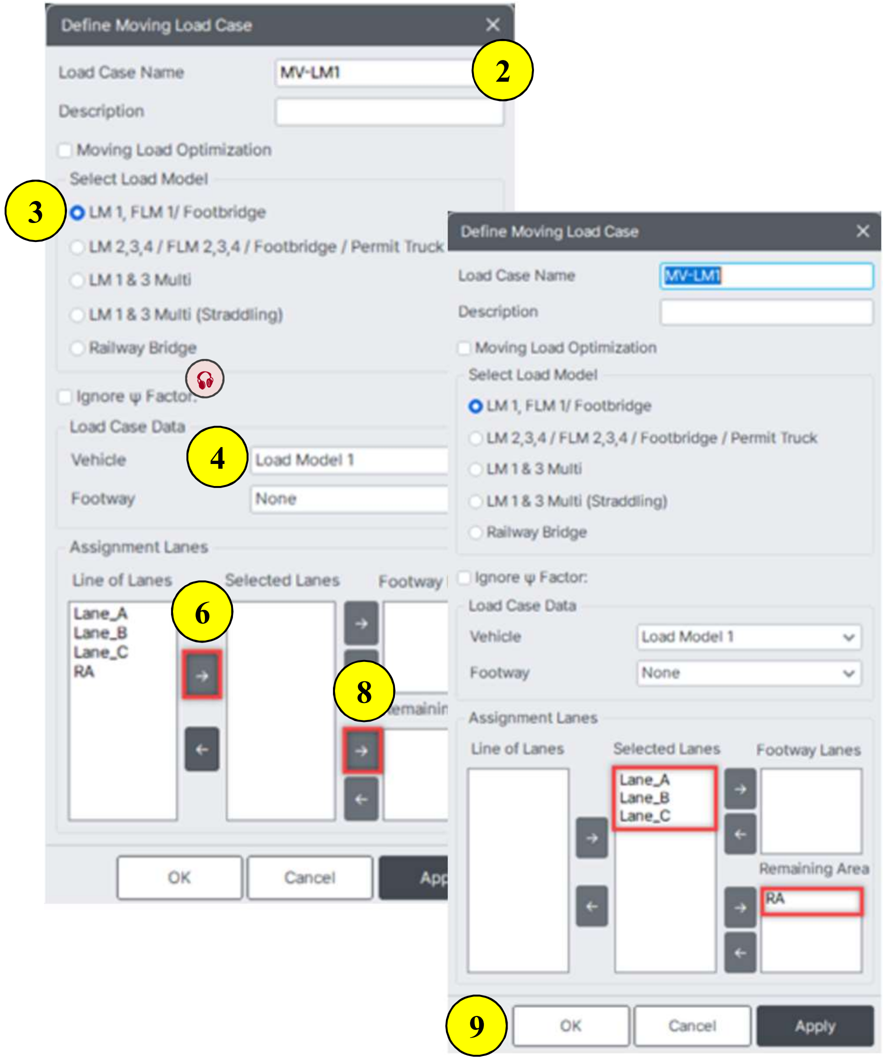
The user can directly change the Adjustment Factor given in the National Annex.

Recommended values of Ψ factors for road bridge

Symbol		Ψ_0	Ψ_1	Ψ_2
grla (LM1+pedestrian or cycle-track loads)	TS	0.75	0.75	0
	UDL	0.40	0.40	0
	Pedestrian + cycle-track loads	0.40	0.40	0
gr1b(Single axle)		0	0.75	0
gr2 (Horizontal forces)		0	0	0
gr3 (Pedestrian loads)		0	0	0
gr4 (LM4-Crowd loading)		0	0.75	0
gr5 (LM3-Special vehicles)		0	0	0

Step5. Define moving load case

(Case 1. Check Load Model 1)

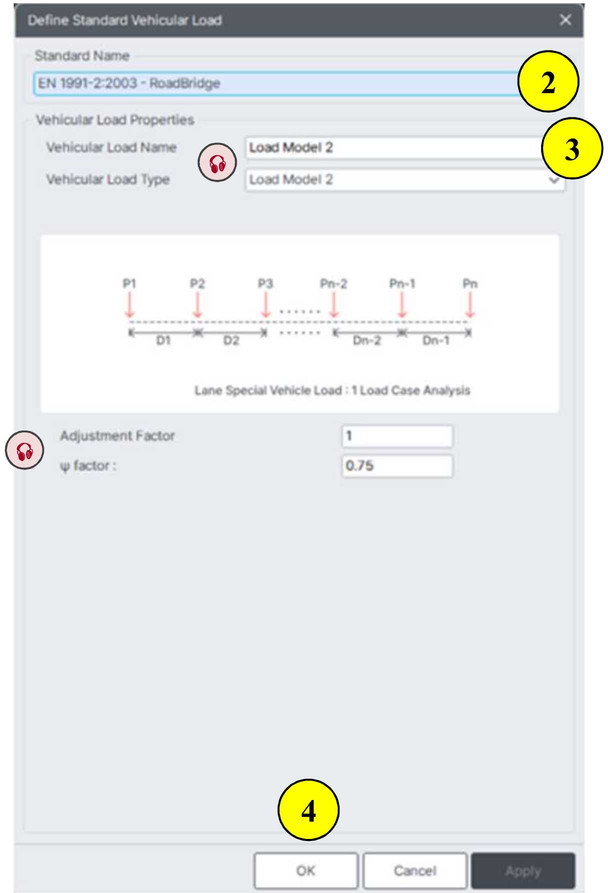


1. *Load > Load Type > Moving Load >* ***Moving Load Cases > [Add] button***
2. *Load Case Name :* ***MV-LM1***
3. *Select Load Model :* ***LM 1, FLM 1***
4. *Vehicle :* ***Load Model 1***
5. *Select* ***Lane_A, Lane_B, Lane_C*** *and* ***RA***.
6. *Click* →.
7. *Select* ***RA.***
8. *Click* →.
9. *Click* **[OK]** *button.*

Load Model 1 should be applied to each notional lane and to the remaining area. Load Model 1 is applied only to the unfavorable parts of the influence line, longitudinally and transversally.

Step6. Define vehicular load

(Case 2. Check Load Model 2)



1. *Load > Load Type > Moving Load > Vehicles > [Add Standard] button*
2. *Standard Name : **EN 1991-2:2003 – RoadBridge***
3. *Vehicular Load Type : **Load Model 2***
4. *Click* **[OK]** *button.*

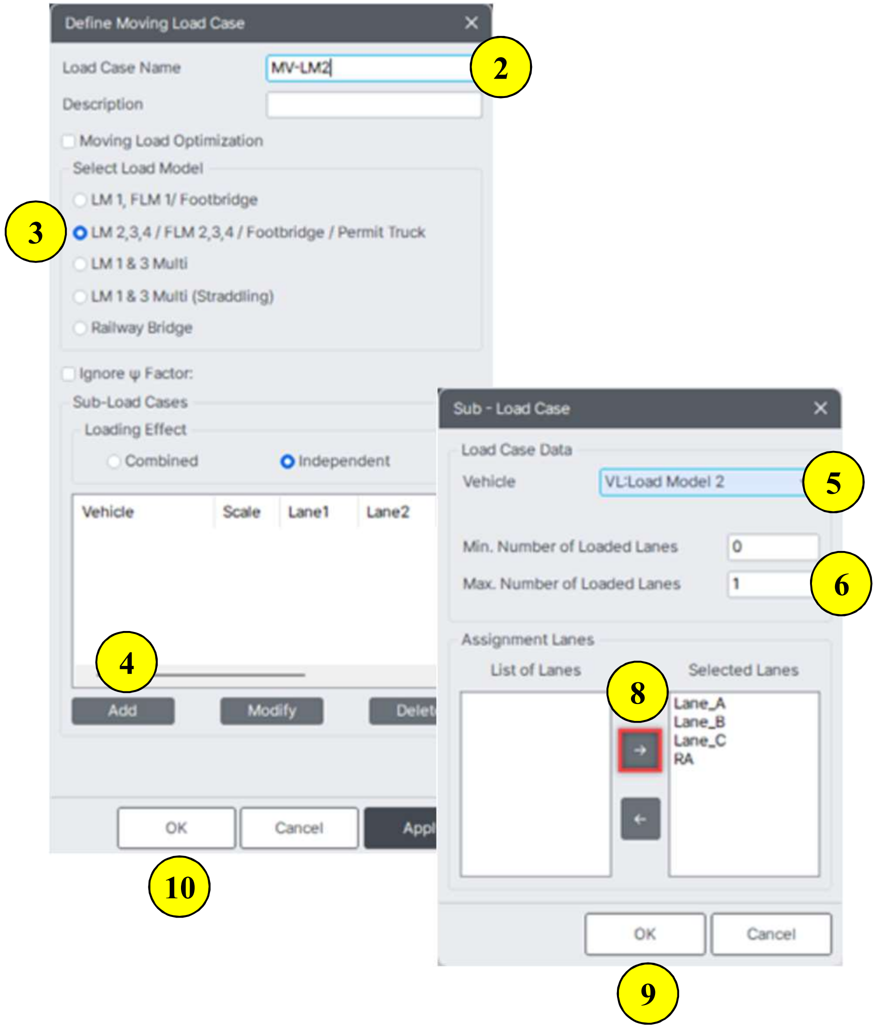
Load Model 2 (LM2) : A single axle load applied to specific tyre contact areas which covers the dynamic effects of the normal traffic on short structural members.

The user can directly change the Adjustment Factor given in the National Annex.

Additional dynamic amplification factor near expansion joints are not taken into account.

Step7. Define moving load case

(Case 2. Check Load Model 2)

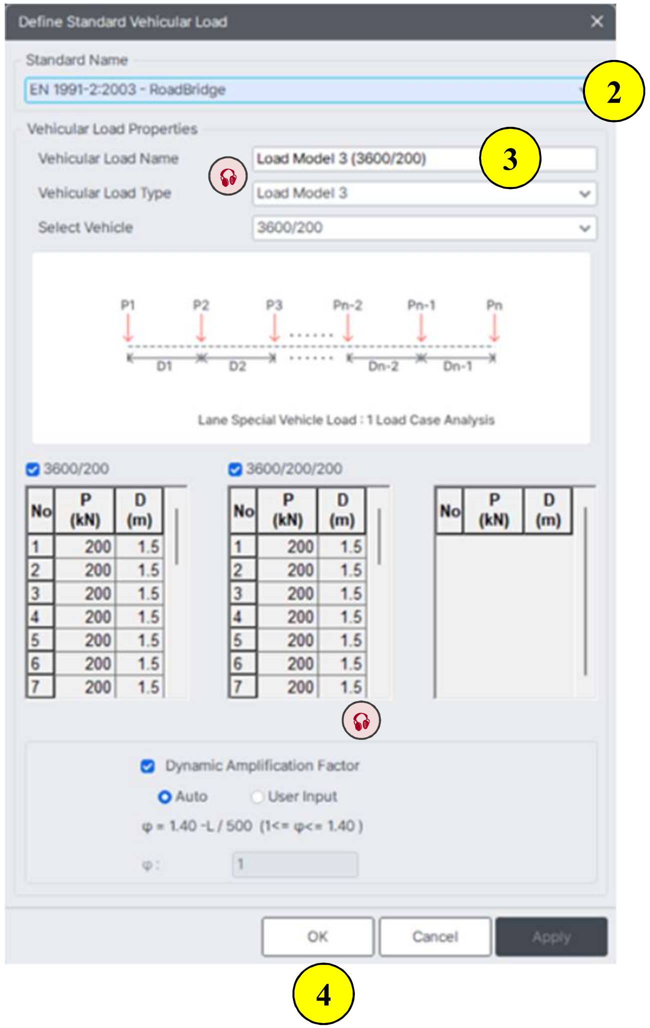


1. *Load > Load Type > Moving Load >* ***Moving Load Cases > [Add] button***
2. *Load Case Name :* ***MV-LM2***
3. *Select Load Model :* ***LM 2,3,4 / FLM 2,3,4 / Footbridge***
4. *Click* **[Add]** *button.*
5. *Vehicle Class :* ***VL:Load Model 2***
6. *Max. Number of Loaded Lanes:* ***1***
7. *Select* ***Lane_A, Lane_B, Lane_C*** *and* ***RA.***
8. *Click* → *.*
9. *Click* **[OK]** *button.*
10. *Click* **[OK]** *button.*

Load Model 2 should be applied to any location on the carriageway.

Step8. Define vehicular load

(Case 3. Check Load Model 3 with the simultaneous presence of Load Model 1)



1. *Load > Load Type > Moving Load > Vehicles > [Add Standard] button*
2. *Standard Name : **EN 1991-2:2003 – RoadBridge***
3. *Vehicular Load Type : **Load Model 3(3600/200)***
4. *Click **[OK]** button.*

Load Model 3 (LM3) : A set of assemblies of axle loads representing special vehicles which can travel on routes permitted for abnormal loads.

A dynamic amplification for Load Model 3 is taken into account automatically.

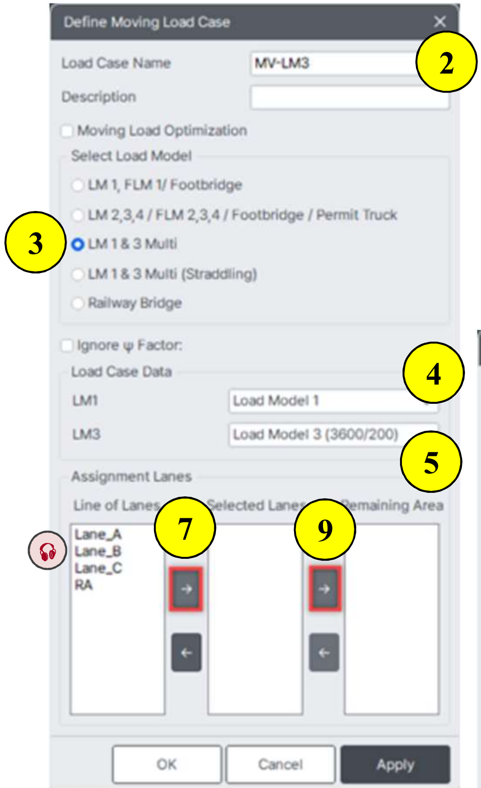
In this tutorial, special vehicle is assumed to move at normal speed.

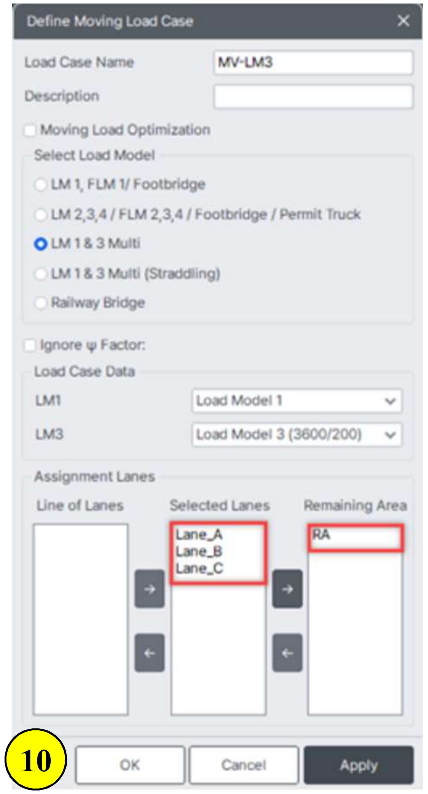
Applicable Axle–lines in MIDAS CIVIL NX

Axle-lines of 150kN	*Axle-lines of 200kN*	*Axle-lines of 240kN*
Available	*Available*	*Not Available*

Step9. Define moving load case

(Case 3. Check Load Model 3 with the simultaneous presence of Load Model 1)

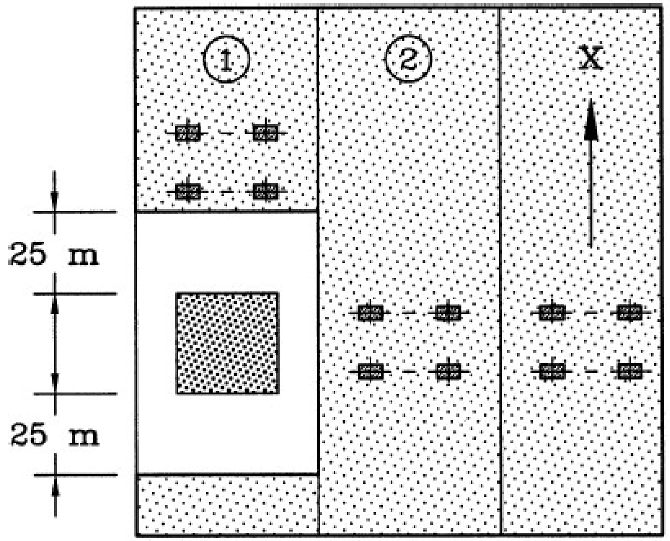




1. ***Load > Load Type > Moving Load >*** ***Moving Load Cases > [Add] button***
2. *Load Case Name :* ***MV-LM3***
3. *Select Load Model :* ***LM 1 & 3 Multi***
4. *LM1 :* ***Load Model 1***
5. *LM3 :* ***Load Model 3 (3600/200)***
6. *Select* ***Lane_A, Lane_B, Lane_C*** *and* ***RA.***
7. *Click* →.
8. *Select* ***RA***.
9. *Click* →.
10. *Click* **[OK]** *button.*

Load Model 3 is applied to Lane_A, Lane_B or Lane_C .

Tip 2. Simultaneity of Load Model 1 and special vehicle



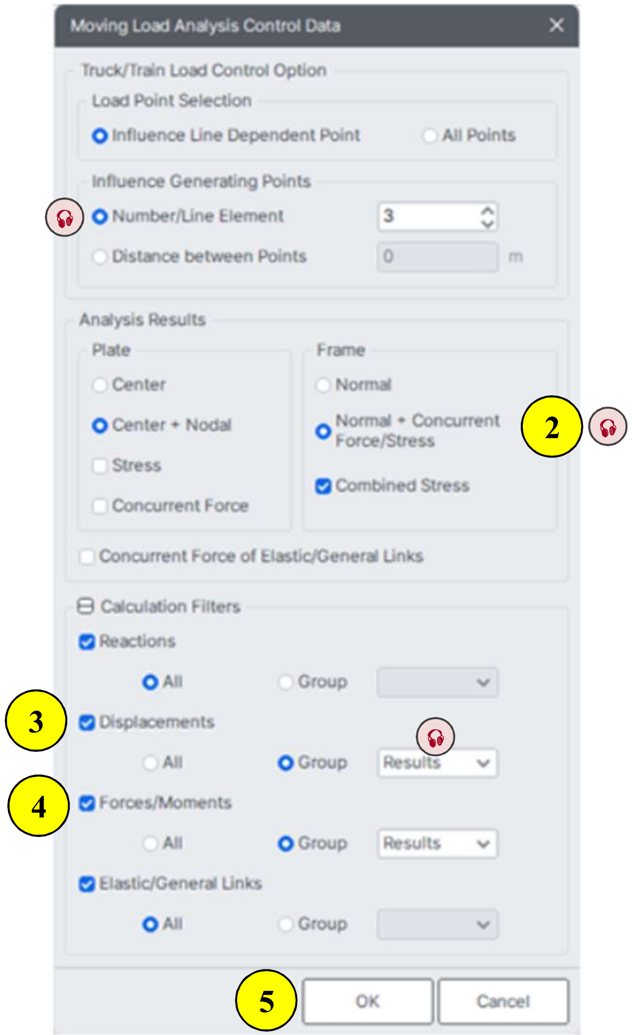
Key
Axle-line of 150 or 200kN
X: Bridge Axis direction
(1) Lane 1
(2) Lane 2

Standardized vehicle

Area loaded with the frequent model of LM1

Where special vehicles are assumed to move at normal speed, a pair of special vehicles should be used in the lane(s) occupied by these vehicles. On the other lanes and the remaining area, the bridge deck should be loaded by Load Model 1 with its frequent values.

Step10. Moving load analysis option



1. *Main Menu > [Analysis] Tab > [Analysis Control] Group > Moving Load*
2. *Frame : **Normal + Concurrent Force***
3. *Displacements Group : **Results***
4. *Forces/Moments Group : **Results***
5. *Click **[OK]** button.*

Number/Line Element : Assign the number of reference points on a line element for moving loads and drawing influence line in an influence line analysis. The accuracy of results increases with the increase in the number, but the analysis time may become excessive.

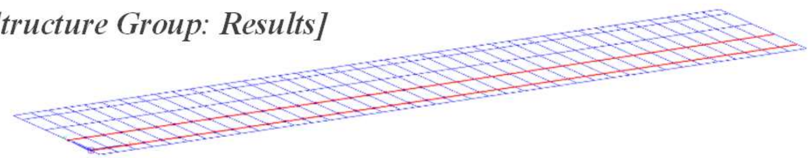
Normal + Concurrent Force : If the output of concurrent forces for max and min values is required for moving load analysis, select 「Normal + Concurrent Force」.

Note

Concurrent forces are not calculated for LM1 & 3 (Multi) model.

Select the specific group for which analysis results need to be checked in order to reduce analysis time.

[Structure Group: Results]

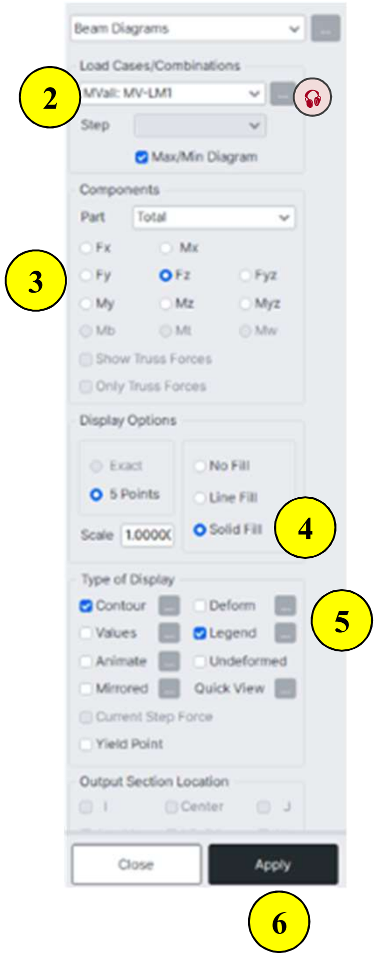


Step 11. Perform analysis

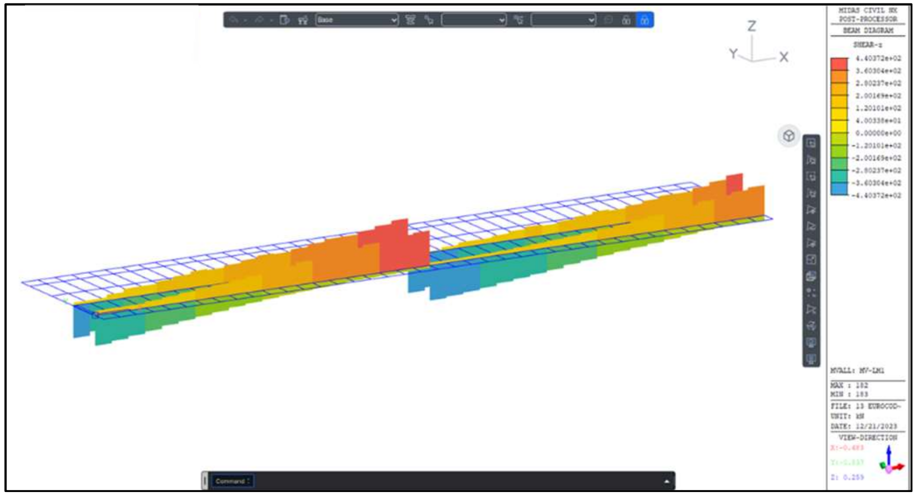
1. Click .

Step 12-1. Shear force diagrams

- ***MVmin** : The minimum force resulting from the vehicle load applied to the structure.*
- ***MVmax**: The maximum force resulting from the vehicle load applied to the structure.*
- ***MVall**: Both maximum and minimum force resulting from the vehicle load applied to the structure.*

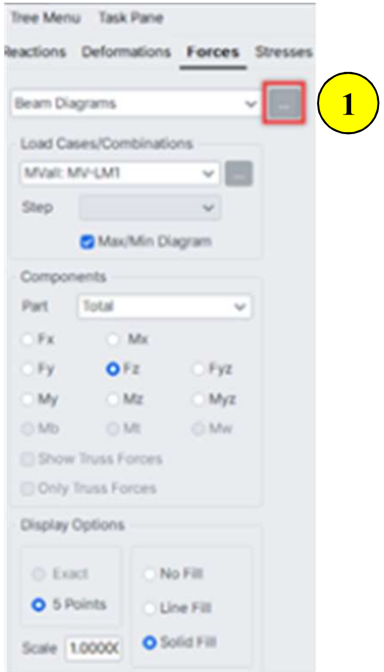


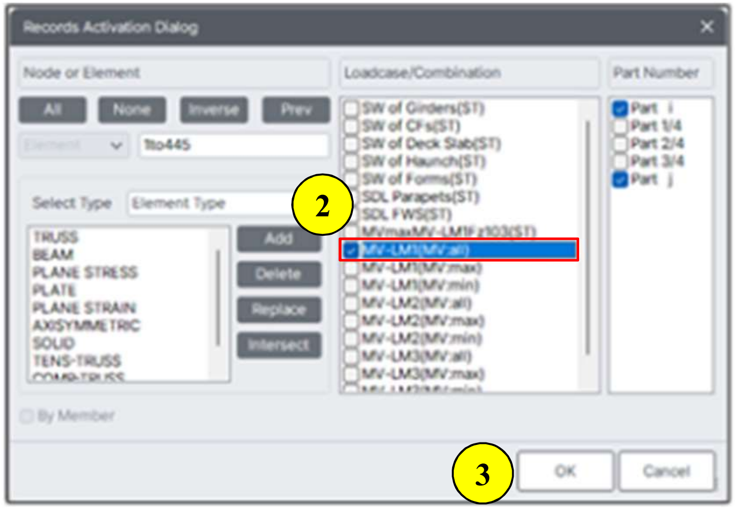
1. ***Main Menu > [Results] Tab > [Result Type] Group > Analysis Result > [Result Display] Group > Forces > Beam Diagrams***
2. *Load Cases/Combinations : **Mvall:MV-LM1***
3. *Components : **Fz***
4. *Display Options : **Solid Fill***
5. *Check on **Contour**, **Legend**.*
6. *Click* **[Apply]** *button.*



Step 12-2. Shear force tables

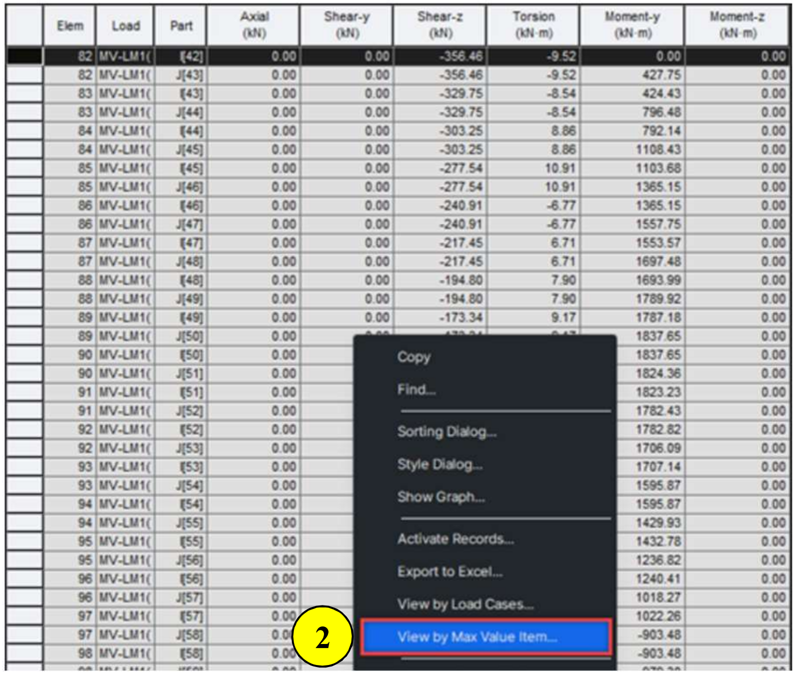
1. *Click* [...] *.*
2. *Check on* ***MV-LM1(MV:all)****.*
3. *Click* **[OK]** *button.*





	Elem	Load	Part	Axial (kN)	Shear-y (kN)	Shear-z (kN)	Torsion (kN·m)	Moment-y (kN·m)	Moment-z (kN·m)
	82	MV-LM1(	I[42]	0.00	0.00	-356.46	-9.52	0.00	0.00
	82	MV-LM1(	J[43]	0.00	0.00	-356.46	-9.52	427.75	0.00
	83	MV-LM1(	I[43]	0.00	0.00	-329.75	-8.54	424.43	0.00
	83	MV-LM1(	J[44]	0.00	0.00	-329.75	-8.54	796.48	0.00
	84	MV-LM1(	I[44]	0.00	0.00	-303.25	8.86	792.14	0.00
	84	MV-LM1(	J[45]	0.00	0.00	-303.25	8.86	1108.43	0.00
	85	MV-LM1(	I[45]	0.00	0.00	-277.54	10.91	1103.68	0.00
	85	MV-LM1(	J[46]	0.00	0.00	-277.54	10.91	1365.15	0.00
	86	MV-LM1(	I[46]	0.00	0.00	-240.91	-6.77	1365.15	0.00
	86	MV-LM1(	J[47]	0.00	0.00	-240.91	-6.77	1557.75	0.00
	87	MV-LM1(	I[47]	0.00	0.00	-217.45	6.71	1553.57	0.00
	87	MV-LM1(	J[48]	0.00	0.00	-217.45	6.71	1697.48	0.00
	88	MV-LM1(	I[48]	0.00	0.00	-194.80	7.90	1693.99	0.00
	88	MV-LM1(	J[49]	0.00	0.00	-194.80	7.90	1789.92	0.00

Step 12-3. Shear force tables (Concurrent forces)

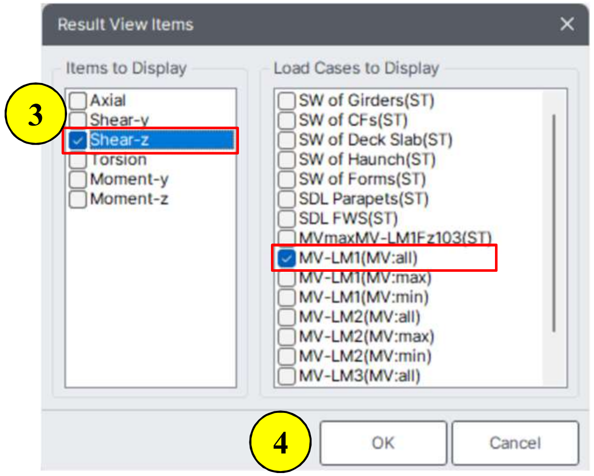


1. Right-click on the Beam Force table.

2. Select ***View by Max Value Item…***

3. Check on ***Shear-z****.*

4. Click **[OK]** *button.*



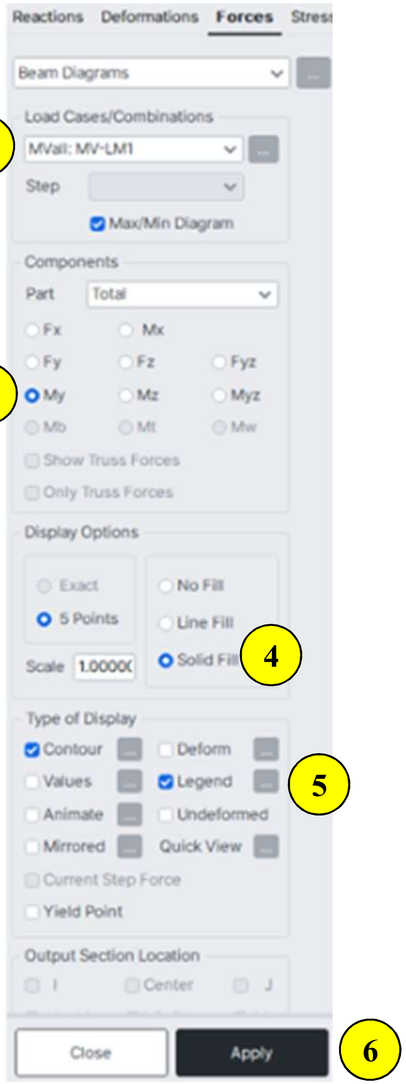
Calculate the corresponding member forces under the conditions where the maximum and minimum member forces occur at each position.

Elem	Load	Part	Component	Axial (kN)	Shear-y (kN)	Shear-z (kN)	Torsion (kN·m)	Moment-y (kN·m)	Moment-z (kN·m)
82	MV-LM1	I[42]	Shear-z	0,00	0,00	-357,52	-4,06	0,00	0,00
82	MV-LM1	J[43]	Shear-z	0,00	0,00	-357,52	-4,06	429,02	0,00
83	MV-LM1	I[43]	Shear-z	0,00	0,00	-330,83	-1,66	396,98	0,00
83	MV-LM1	J[44]	Shear-z	0,00	0,00	-330,83	-1,66	793,97	0,00
84	MV-LM1	I[44]	Shear-z	0,00	0,00	-304,39	0,24	728,87	0,00
84	MV-LM1	J[45]	Shear-z	0,00	0,00	-304,39	0,24	1094,14	0,00
85	MV-LM1	I[45]	Shear-z	0,00	0,00	-278,64	2,47	999,08	0,00
85	MV-LM1	J[46]	Shear-z	0,00	0,00	-278,64	2,47	1333,45	0,00

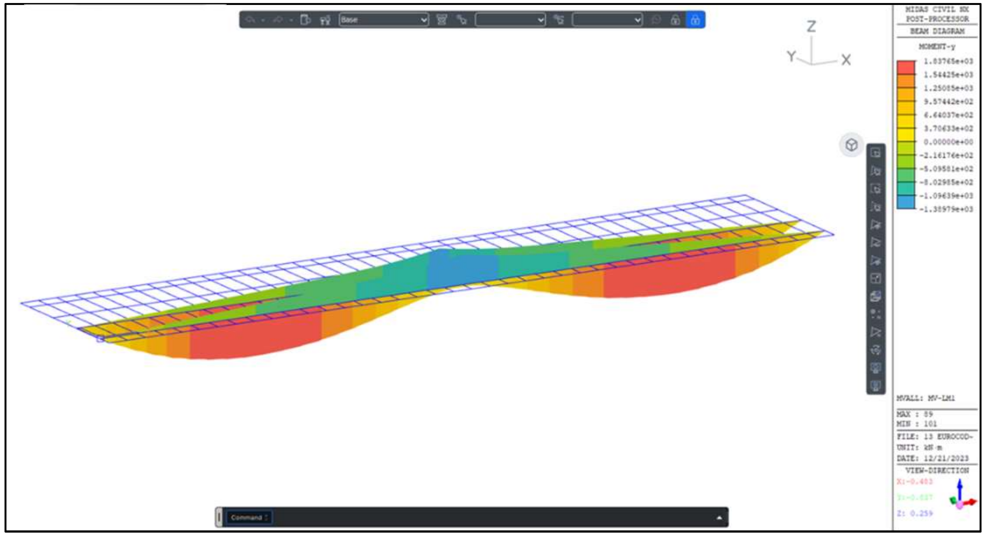
Result By Max Value-[Beam Force]

Model View | Result-[Beam Force] | Result By Max Value-[Beam Force]

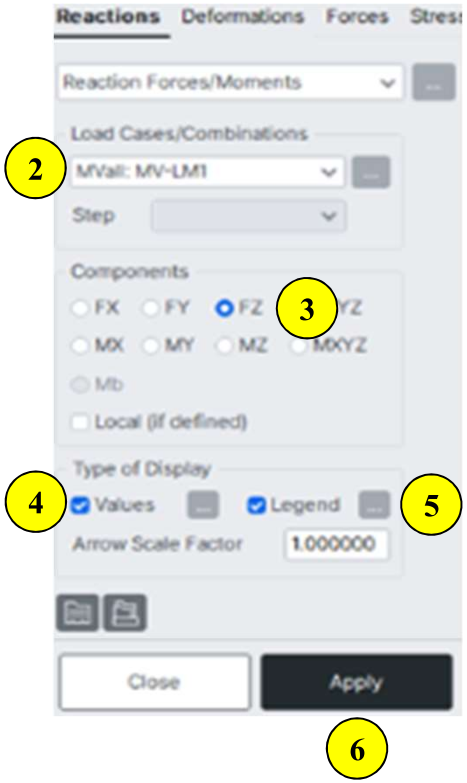
Step 13. Bending moment diagrams



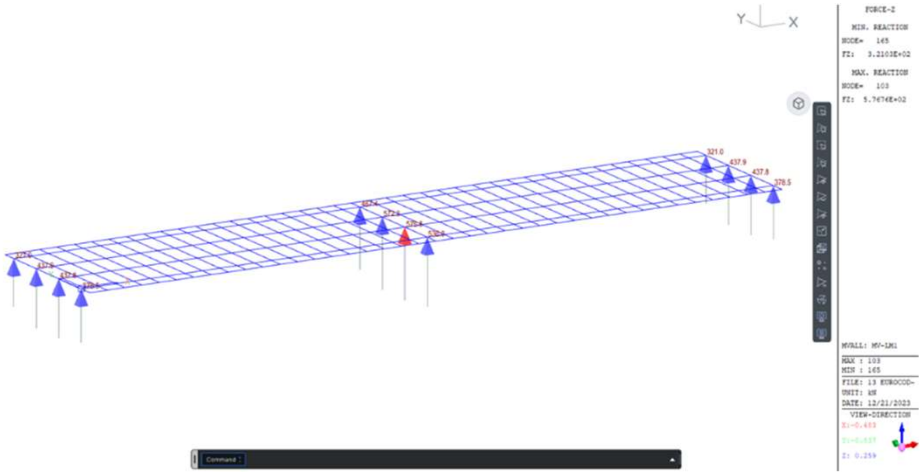
1. ***Main Menu > [Results] Tab > [Result Type] Group > Analysis Result > [Result Display] Group > Forces >*** ***Beam Diagrams***
2. *Load Cases/Combinations :* ***MVall:MV-LM1***
3. *Components :* ***My***
4. *Display Options :* ***Solid Fill***
5. *Check on* ***Legend****.*
6. *Click* **[Apply]** *button.*



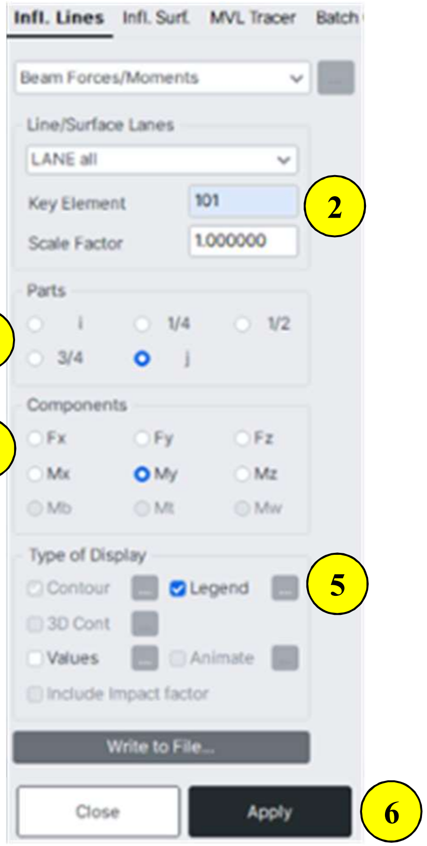
Step 14. Reactions



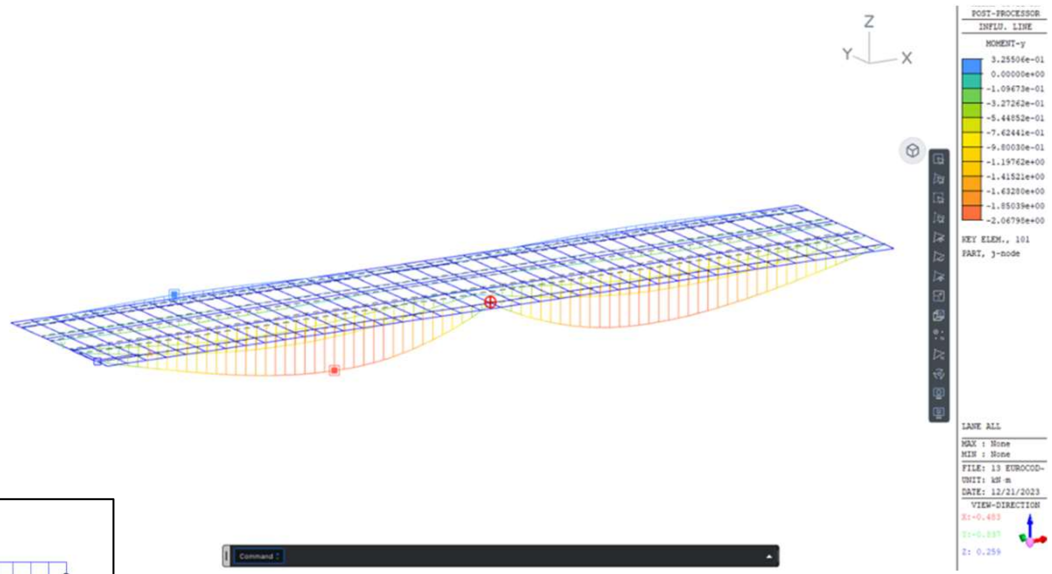
1. **Main Menu > [Results] Tab > [Result Type] Group > Analysis Result > [Result Display] Group > Reactions > Reaction Forces/Moments**
2. Load Cases/Combinations : ***MVmax:MV-LM1***
3. Components : ***Fz***
4. Check on ***Values***.
5. Check on ***Legend***.
6. Click **[Apply]** button.



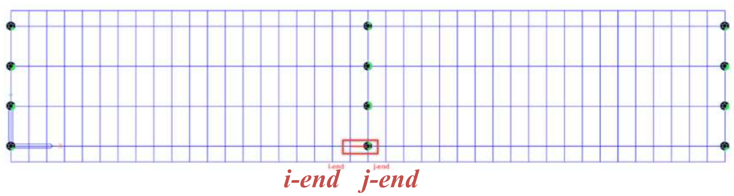
Step 15. Influence lines



1. ***Main Menu > [Results] Tab > [Result Type] Group > Analysis Result > [Moving Load] Group > Influ. Lines > Beam Forces/Moments***
2. *Key Element:* ***101***
3. *Parts:* ***j***
4. *Components:* ***My***
5. *Check on* ***Legend***
6. *Click* **[Apply]** *button.*



Key Element: 101

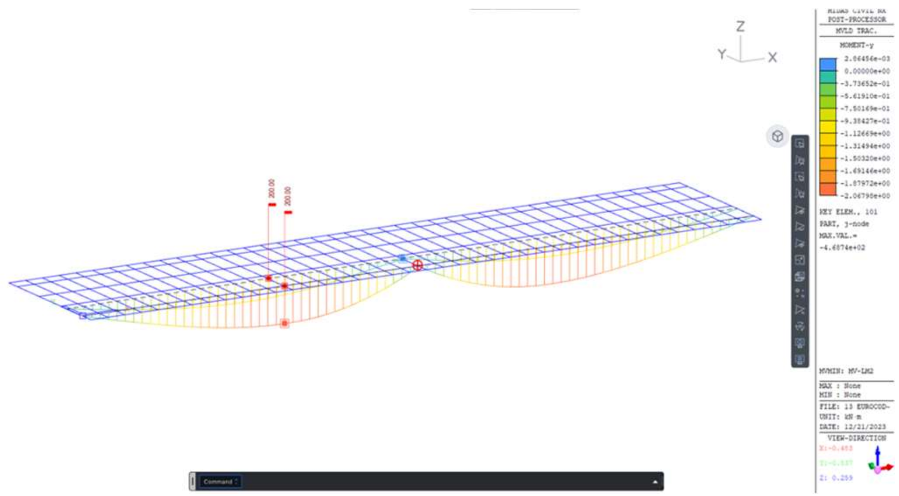


Step 16-1. Moving load tracer

Display moving load location that results in the minimum moment at the j-end of the element no. 101 due to the "MV-LM2" load case.

Trace and graphically display the vehicle loading condition (corresponding moving load case and location) that results in the maximum/ minimum force of a beam element. The loading condition is converted into a static loading and produced as a model file of the MCT type by clicking [Write Min/Max Load to File] button.

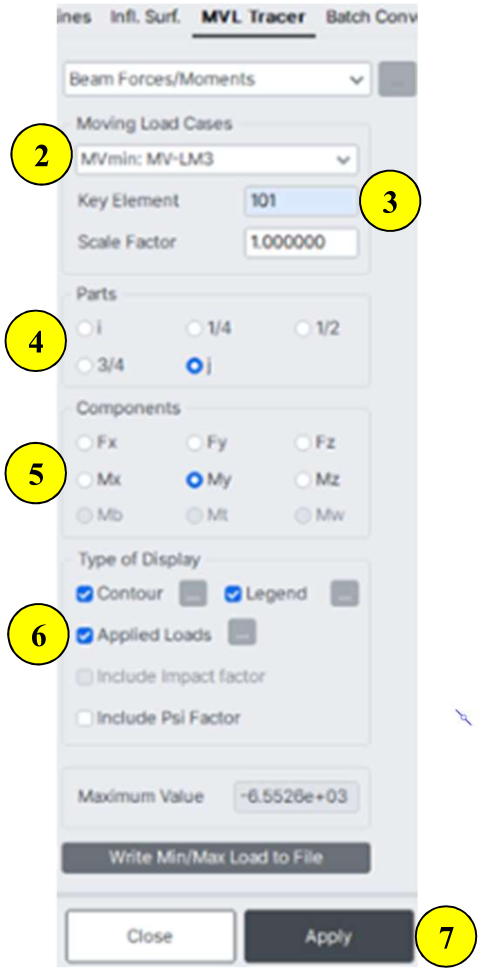
1. *Main Menu > [Results] Tab > [Result Type] Group > Analysis Result > [Moving Load] Group > Moving Tracer > Beam Forces/Moments*
2. *Moving Load Cases:* ***MVmin:MV-LM2***
3. *Key Element:* ***101***
4. *Parts:* ***j***
5. *Components:* ***My***
6. *Check on* ***Contour, Legend*** *and* ***Applied Loads.***
7. *Click* **[Apply]** *button.*

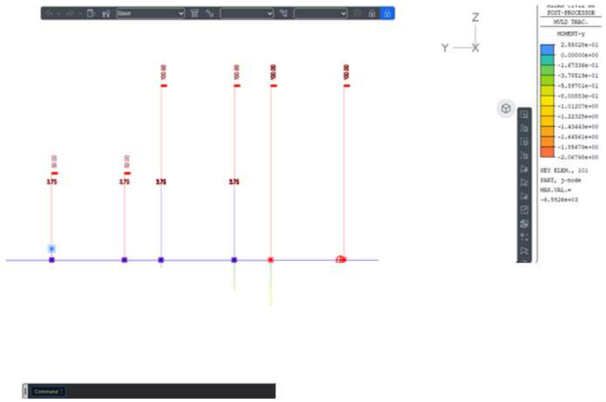


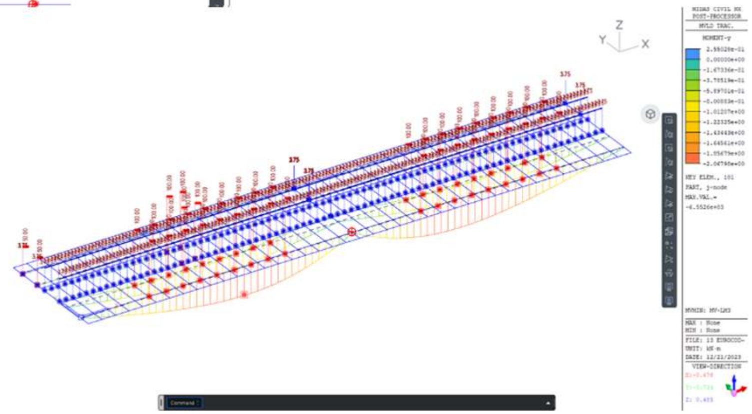
Step 16-2. Moving load tracer

Display moving load location that results in the minimum moment at the j-end of the element no. 101 due to the "MV-LM3" load case.

1. ***Main Menu > [Results] Tab > [Result Type] Group > Analysis Result > [Moving Load] Group > Moving Tracer > Beam Forces/Moments***
2. *Moving Load Cases:* ***MVmin:MV-LM3***
3. *Key Element:* ***101***
4. *Parts:* ***j***
5. *Components:* ***My***
6. *Check on* ***Contour, Legend*** *and* ***Applied Loads.***
7. *Click* **[Apply]** *button.*



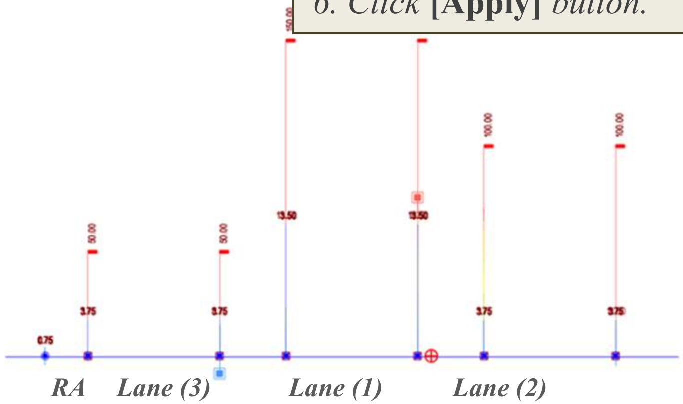


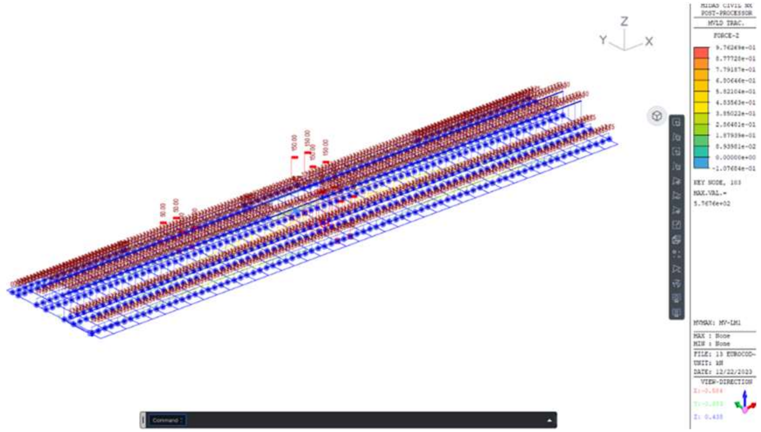


Step 16-3. Moving load tracer

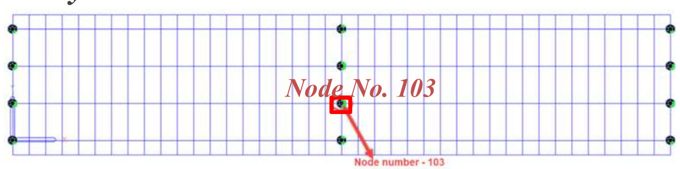
Display moving load location that results in the maximum reaction of the node no. 103 due to the "MV-LM1" load case.

1. ***Main Menu > [Results] Tab > [Result Type] Group > Analysis Result > [Moving Load] Group > Moving Tracer > Reactions***
2. *Moving Load Cases:* ***MVmax:MV-LM1***
3. *Key Node:* ***103***
4. *Components:* ***Fz***
5. *Check on* ***Contour, Legend*** *and* ***Applied Loads****.*
6. *Click* **[Apply]** *button.*



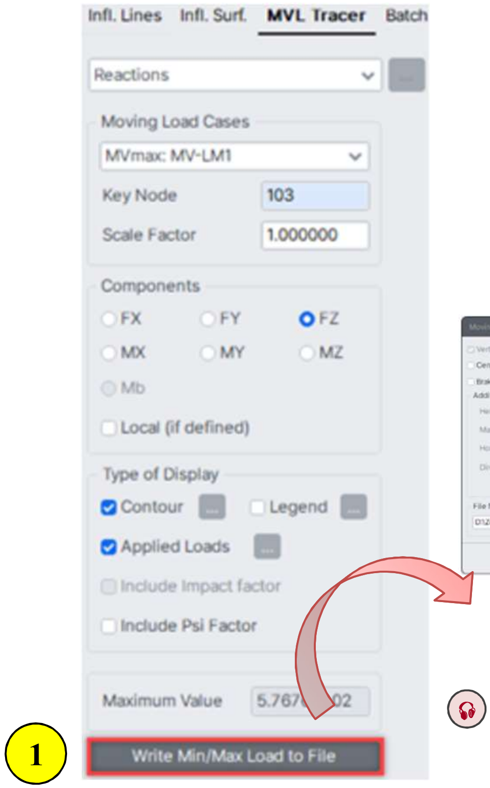


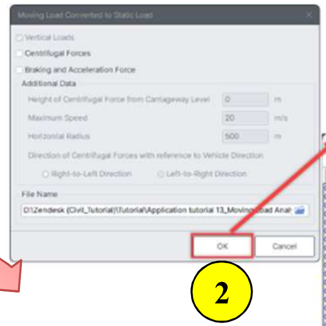
Key Node: 103

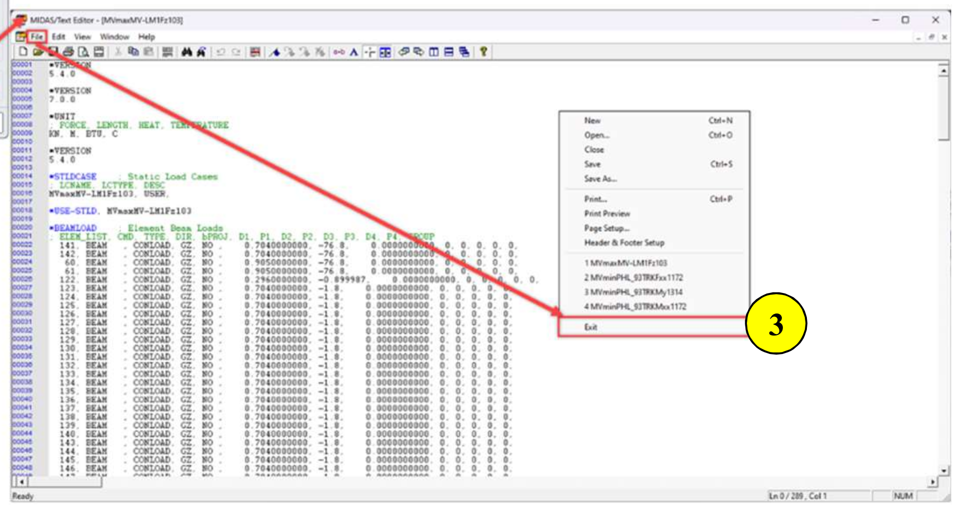


Step 17-1. Converting the moving load into a static load

1. *Click* **[Write Min/Max Load to File]** *button.*
2. *Click* **[OK]** *button.*
3. *Select* ***File > Exit*** *in the* ***MIDAS/Text Editor****.*



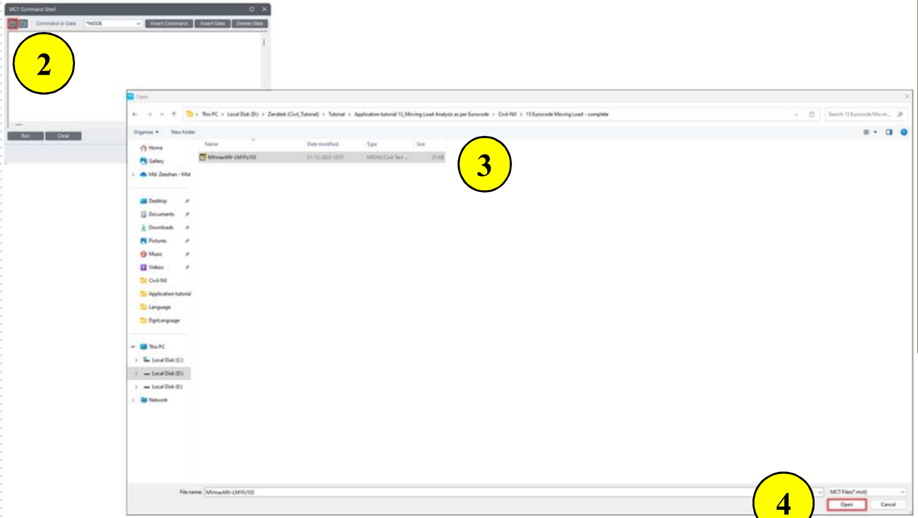


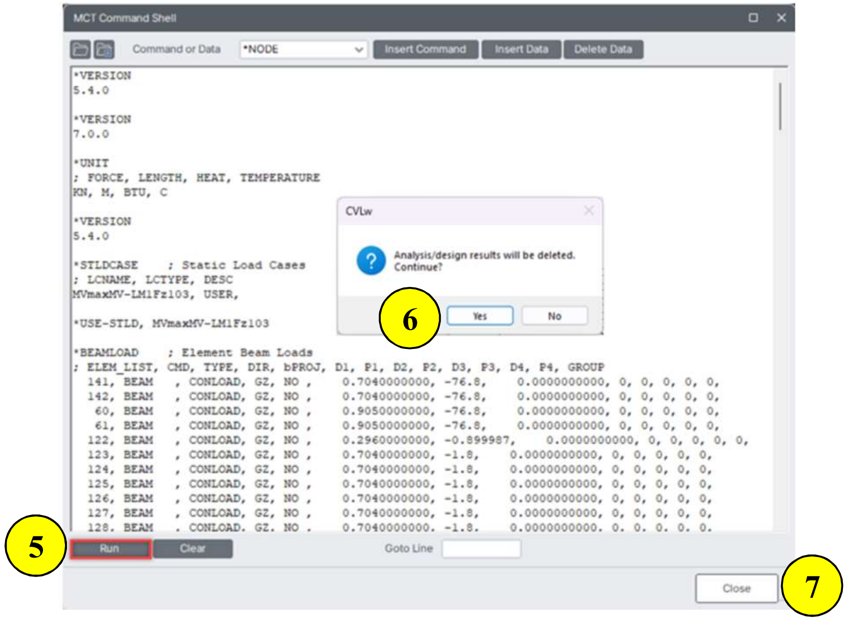


Where moving load analysis has been carried out, the moving load case, which produces the maximum or minimum results, is converted into a static loading and produced as the MCT type.

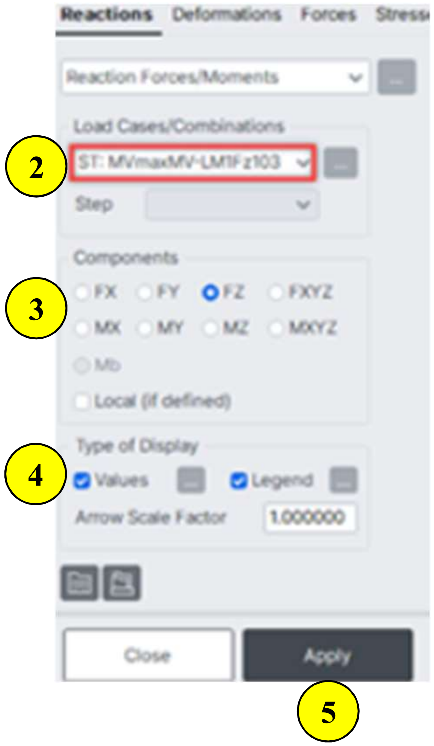
Step 17-2. Converting the moving load into a static load

1. ***Main Menu > [Apps] Tab >*** ***MCT Command Shell***
2. *Click* .
3. *Select the file name* ***"MVmaxMV-LM1Fz103.mct".***
4. *Click* **[Open]** *button.*
5. *Click* **[Run]** *button.*
6. *Click* **[Yes]** *button.*
7. *Click* **[Close]** *button.*
8. *Click* ***Perform Analysis.***

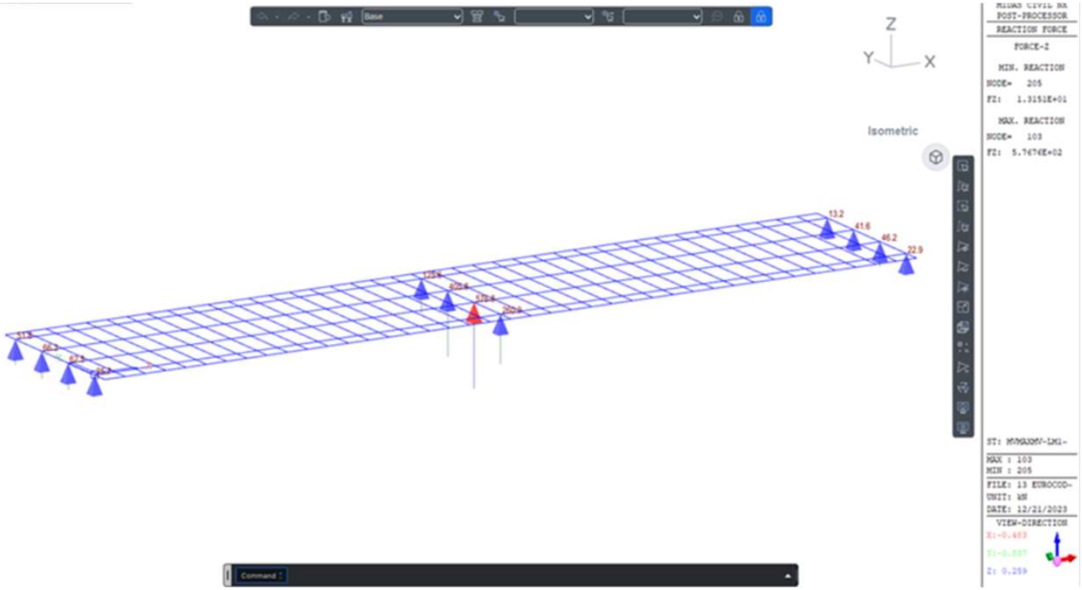




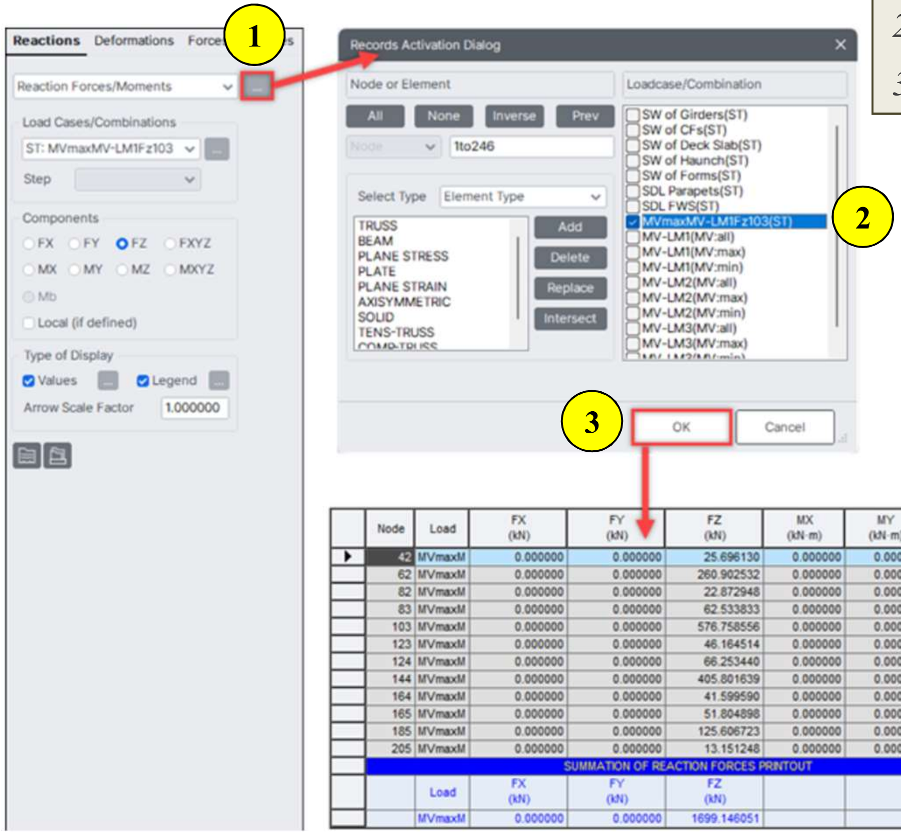
Step 18-1. Check beam reactions due to the converted static load



1. *Main Menu > [Results] Tab > [Result Type] Group > Analysis Results > [Result Display] Group > Reactions > Reaction Forces/Moments*
2. *Load Cases/Combinations:* ***ST:MVmaxMV-LM1Fz103***
3. *Components:* ***Fz***
4. *Check on* ***Values*** *and* ***Legend****.*
5. *Click* **[Apply]** *button.*



Step 18-2. Check reaction table due to the static load



Node	Load	FX (kN)	FY (kN)	FZ (kN)	MX (kN·m)	MY (kN·m)	MZ (kN·m)
42	MVmaxM	0.000000	0.000000	25.696130	0.000000	0.000000	0.000000
62	MVmaxM	0.000000	0.000000	260.902532	0.000000	0.000000	0.000000
82	MVmaxM	0.000000	0.000000	22.872948	0.000000	0.000000	0.000000
83	MVmaxM	0.000000	0.000000	62.533833	0.000000	0.000000	0.000000
103	MVmaxM	0.000000	0.000000	576.758556	0.000000	0.000000	0.000000
123	MVmaxM	0.000000	0.000000	46.164514	0.000000	0.000000	0.000000
124	MVmaxM	0.000000	0.000000	66.253440	0.000000	0.000000	0.000000
144	MVmaxM	0.000000	0.000000	405.801639	0.000000	0.000000	0.000000
164	MVmaxM	0.000000	0.000000	41.599590	0.000000	0.000000	0.000000
165	MVmaxM	0.000000	0.000000	51.804898	0.000000	0.000000	0.000000
185	MVmaxM	0.000000	0.000000	125.606723	0.000000	0.000000	0.000000
205	MVmaxM	0.000000	0.000000	13.151248	0.000000	0.000000	0.000000
SUMMATION OF REACTION FORCES PRINTOUT							
	Load	FX (kN)	FY (kN)	FZ (kN)			
	MVmaxM	0.000000	0.000000	1699.146051			

1. Click [...]*.*
*2. Check on **MVmaxMV-LM1Fz103(ST)**.*
*3. Click **[OK]** button.*

Reaction table due to static load case 'MVmaxMV-LM1Fz103' displays the concurrent reactions due to the moving load case 'MV-LM1' when the reaction of the node no. 103 is maximum.