Train Load Analysis

- *EN 1991-2:2003*

- **Product: midas Civil**
- **Version: Civil 2013**
- ***Date: August 31, 2012***

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1. Relevant Eurocodes for railway bridge

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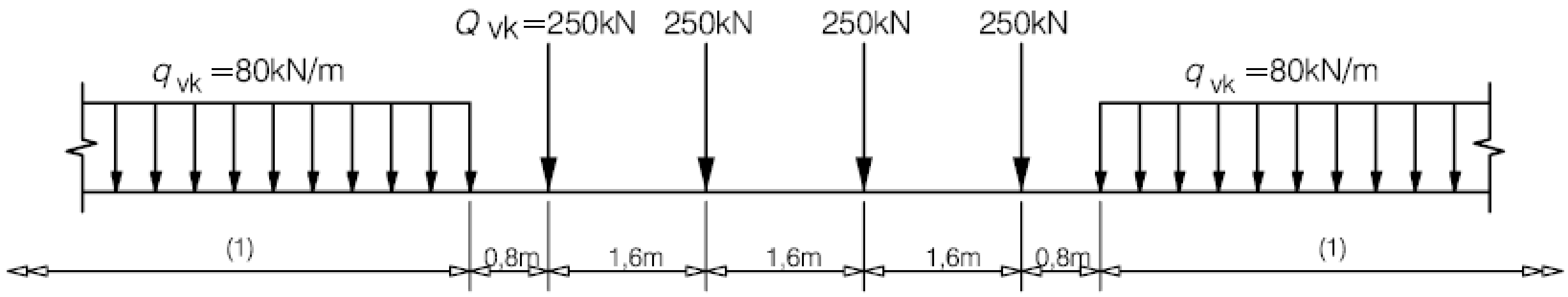
2. Railway Actions

- *Actions due to railway operations:*
  - *Vertical loads: Load Models 71, SW (SW/0 and SW/2), "unloaded train" and HSLM*
  - *Dynamic effects*

❑ *Actions to be considered separately by the user*

- *Vertical loading for earthworks*
- *Centrifugal forces*
- *Nosing force*
- *Traction and braking forces*
- *Aerodynamic actions from passing trains*
- *Actions due to overhead line equipment and other railway infrastructure and equipment*
- *Actions for non-public footpaths*

3. Vertical loads – Load Model 71



Key
(1) No limitation

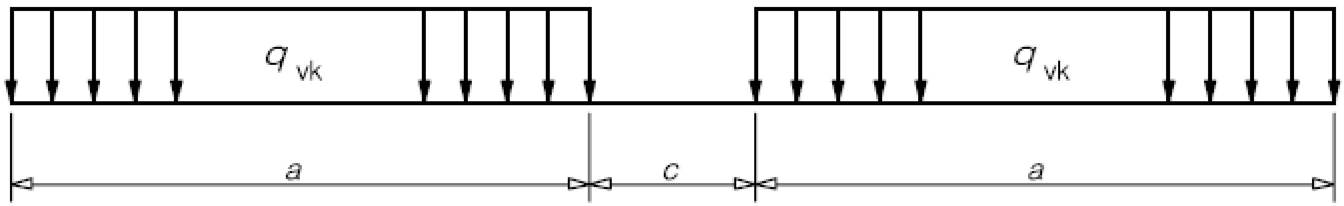
• The characteristic values shall be multiplied by a factor α, on lines carrying rail traffic which is heavier or lighter than normal rail traffic. When multiplied by the factor the loads are called "classified vertical loads".
This factor α shall be one of the following:

0.75 – 0.83 – 0.91 – 1.00 – 1.10 – 1.21 – 1.33 - 1.46

• The actions listed below shall be multiplied by the same factor α:
– equivalent vertical loading for earthworks and earth pressure effects,
– centrifugal forces,
– nosing force (multiplied by α for α ≥ 1 only),
– traction and braking forces,
– combined response of structure and track to variable actions,
– derailment actions for Accidental Design Situations,
– Load Model SW/0 for continuous span bridges.

• For checking limits of deflection classified vertical loads and other actions enhanced by α shall be used (except for passenger comfort where shall be taken as unity).

4. Vertical loads – Load Model SW/0 and SW/2



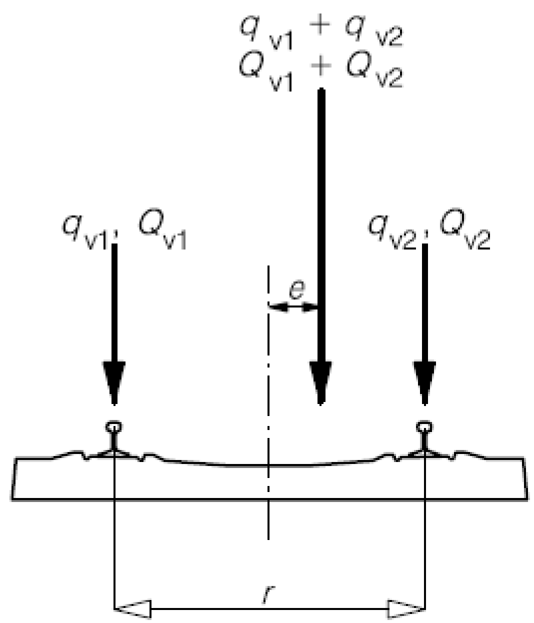
Load Model	q_{vk} [kN/m]	a [m]	c [m]
SW/0	133	15,0	5,3
SW/2	150	25,0	7,0

- **Load Model SW/0 represents the static effect of vertical loading due to normal rail traffic on continuous beams.**
- **Load Model SW/2 represents the static effect of vertical loading due to heavy rail traffic.**
- **Load Model SW/0 shall be multiplied by the factor α.**

5. Eccentricity of vertical loads (Load Models 71 and SW/0)

- The effect of lateral displacement of vertical loads shall be considered by taking the ratio of wheel loads on all axles as up to 1,25:1,00 on any one track.

- Eccentricity of vertical loads may be neglected when considering fatigue.



$$q_{v1}, q_{v2}, Q_{v1}, Q_{v2} = (1)$$

$$q_{v1} + q_{v2}, Q_{v1} + Q_{v2} = (2)$$

$$\frac{q_{v2}}{q_{v1}}, \frac{Q_{v2}}{Q_{v1}} \leq 1{,}25$$

$$e \leq \frac{r}{18}$$

$$r = (3)$$

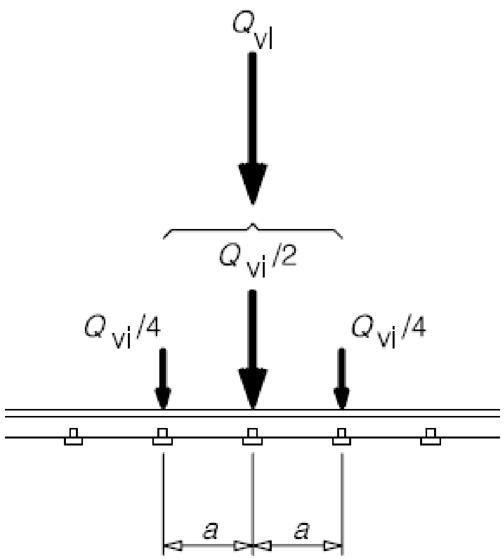
Key

(1) Uniformly distributed load and point loads on each rail as appropriate
(2) LM 71 (and SW/0 where required)
(3) Transverse distance between wheel loads

Note: This eccentricity is not considered in the program.

6. Distribution of axle loads by the rails, sleepers and ballast

1) Longitudinal distribution of a point force or wheel load by the rail



Key

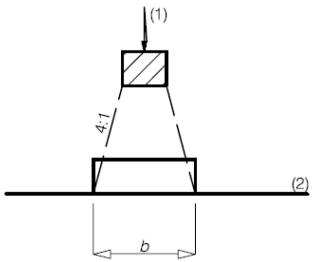
Q_{vi} is the point force on each rail due to Load Model 71 or a wheel load of a Real Train in accordance with 6.3.5, Fatigue Train or HSLM (except for HSLM-B)

a is the distance between rail support points

- **A point force in Load Model 71 and HSLM (except for HSLM-B) or wheel load may be distributed over three rail support points.**

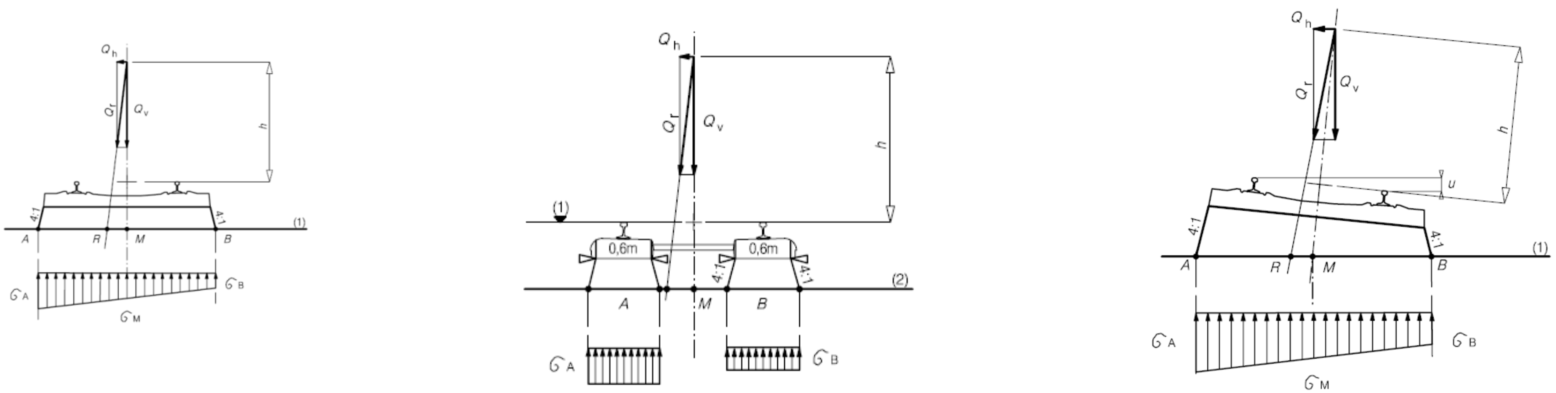
6. Distribution of axle loads by the rails, sleepers and ballast (continued)

2) Longitudinal distribution of load by sleepers and ballast



Note: Not considered in the program.

3) Transverse distribution of actions by the sleepers and ballast



Note: Not considered in the program.

4) Equivalent vertical loading for earthworks and earth pressure effects

Note: Not considered in the program.

7. Dynamic effects

- Factors influencing dynamic behavior

- the speed of traffic across the bridge,
- the span L of the element and the influence line length for deflection of the element being considered,
- the mass of the structure,
- the natural frequencies of the whole structure and relevant elements of the structure and the associated mode shapes along the line of the track,
- the number of axles, axle loads and the spacing of axles,
- the damping of the structure,
- vertical irregularities in the track,
- the unsprung/sprung mass and suspension characteristics of the vehicle,
- the presence of regularly spaced supports of the deck slab and/or track (cross girders, sleepers etc.),
- vehicle imperfections (wheel flats, out of round wheels, suspension defects etc.),
- the dynamic characteristics of the track (ballast, sleepers, track components etc.).

- The dynamic enhancement of load effects shall be allowed for by multiplying the static loading by the dynamic factor Φ. If a dynamic analysis is necessary, the results of the dynamic analysis shall be compared with the results of the static analysis enhanced by Φ and the most unfavorable load effects shall be used for the bridge design.

- The dynamic effects of a Real Train may be represented by a series of travelling point forces. Vehicle/structure mass interaction effects may be neglected. For spans less than 30 m dynamic vehicle/bridge mass interaction effects tend to reduce the peak response at resonance. Account may be taken of these effects by:

– carrying out a dynamic vehicle/structure interactive analysis, (*Not available in the program)
– increasing the value of damping assumed for the structure (*Available in the program)

Note: This tutorial covers the static analysis enhanced by the dynamic factor Φ.

8. Dynamic factor Φ

- A static analysis shall be carried out with the load models (LM71 and where required Load Models SW/0 and SW/2). The results shall be multiplied by the dynamic factor Φ (and if required multiplied by α).
- The dynamic factor takes account of the dynamic magnification of stresses and vibration effects in the structure but does not take account of resonance effects.
- Structures carrying more than one track should be considered without any reduction of dynamic factor Φ.
- Generally the dynamic factor is taken as either 2 or 3 according to the quality of track maintenance as follows:

(a) For carefully maintained track:

$$\Phi_2 = \frac{1{,}44}{\sqrt{L_\Phi} - 0{,}2} + 0{,}82$$

with: $1{,}00 \le \Phi_2 \le 1{,}67$

(b) For track with standard maintenance:

$$\Phi_3 = \frac{2{,}16}{\sqrt{L_\Phi} - 0{,}2} + 0{,}73$$

with: $1{,}00 \le \Phi_3 \le 2{,}0$

L_Φ : Determinant length

- The dynamic factor shall not be used with:
  – the loading due to Real Trains,
  – the loading due to Fatigue Trains,
  – Load Model HSLM,
  – the load model “unloaded train”.

Note: Dynamic factor can automatically be calculated using user-defined determinant length in the program.

9. Determinant length

Structural element (Main girder)	Determinant length
Simply supported girders and slabs	Span in main girder direction
Girders and slabs continuous over n spans with $L_m = 1/n\ (L_1 + L_2 + .. + L_n)$	$L_\Phi = k \times L_m$, but not less than max L_i ($i = 1,\dots, n$) $n = 2 \quad 3 \quad 4 \quad \geq 5$ $k = 1{,}2 \quad 1{,}3 \quad 1{,}4 \quad 1{,}5$

Note: Determinant length needs to be defined by the user in the program.

10. Reduced dynamic effects

In the case of arch bridges and concrete bridges of all types with a cover of more than 1.00 m, Φ_2 and Φ_3 may be reduced as follows:

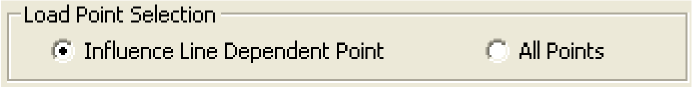
$$red\ \Phi_{2,3} = \Phi_{2,3} - \frac{h - 1{,}00}{10} \geq 1{,}0$$

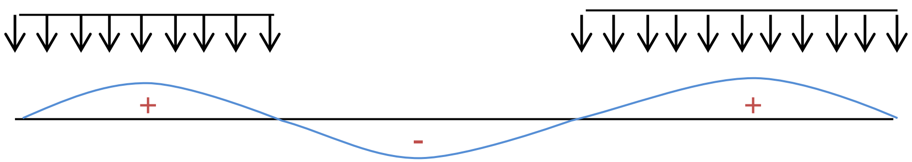
11. Application of traffic loads on railway bridges

The required number and position(s) of the tracks may be specified for the individual project.

The minimum spacing of tracks and structural gauge clearance requirements may be specified for the individual project.

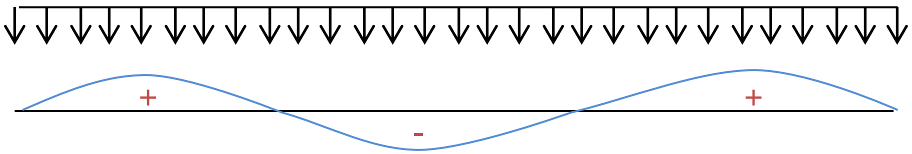
The effects of all actions shall be determined with the traffic loads and forces placed in the most unfavorable positions. Traffic actions which produce a relieving effect shall be neglected. The program provides an option for this effect, which is called 'Load Point Selection' under the 'Moving Load Analysis Control' dialog.





Influence line

'Influence Line Dependent Point' is selected.



Influence line

'All Points' is selected.

11. Application of traffic loads on railway bridges (continued)

- **Load Model 71**

– any number of lengths of the uniformly distributed load *qvk shall be applied to a* track and up to four of the individual concentrated loads *Qvk shall be applied once* per track,

– for structures carrying two tracks, Load Model 71 shall be applied to one track or both tracks,

– for structures carrying three or more tracks, Load Model 71 shall be applied to one track or to two tracks or 0,75 times Load Model 71 to three or more of the tracks.

- **Load Model SW/0**

– the loading shall be applied once to a track,

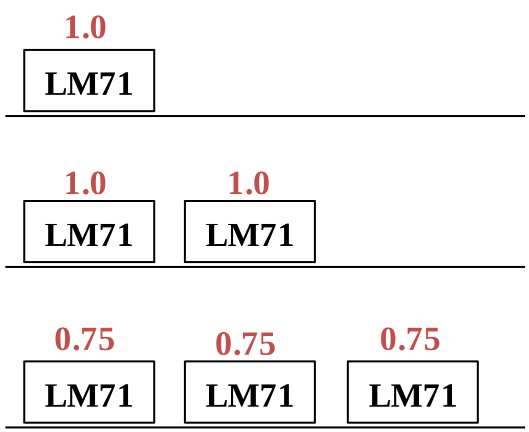
– for structures carrying two tracks, Load Model SW/0 shall be applied to one track or both tracks,

– for structures carrying three or more tracks, Load Model SW/0 shall be applied to one track or to two tracks or 0,75 times Load Model SW/0 to three or more of the tracks.

The program applies Multiple Presence Factor to LM 71 and SW/0 only, which is considered in the 'Moving Load Case' dialog.

Mutiple Presence Factor (LM71 and SW/0)

Num of Loaded Lanes	Scale Factor
1	1
2	1
3 or more	0.75



Transverse cross-section

11. Application of traffic loads on railway bridges (continued)

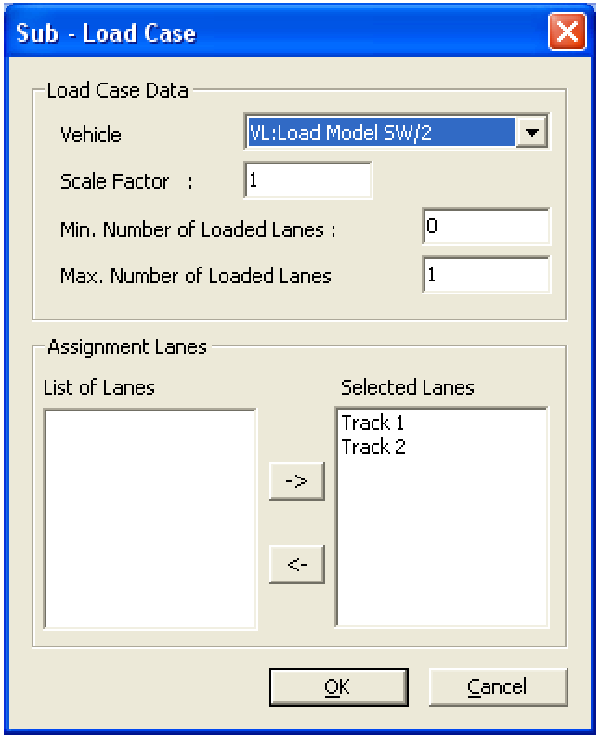
- **Load Model SW/2**

– the loading shall be applied once to a track,

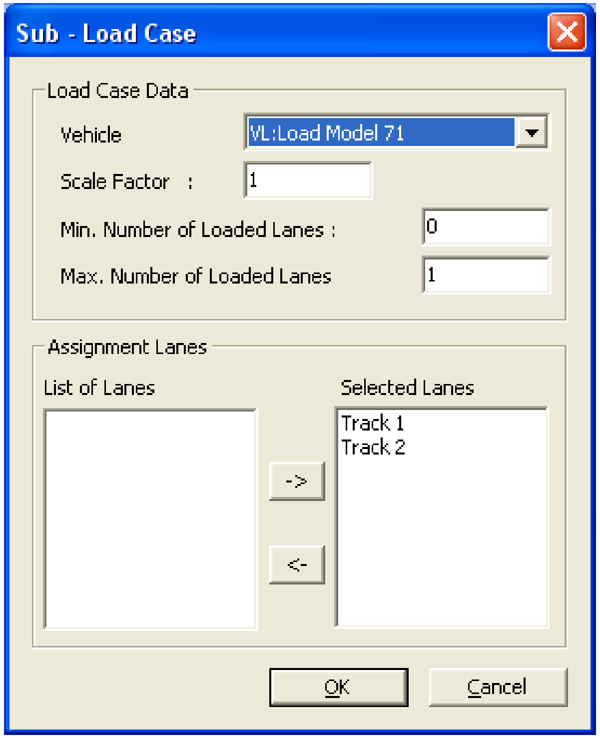
– for structures carrying more than one track, Load Model SW/2 shall be applied to one track only with Load Model 71 or Load Model SW/0 applied to one other track.

- This application case can be considered by defining two sub-load cases and selecting 'Combined' option in a moving load case. One sub-load case for assigning SW/2 with Max. Number of Loaded Lanes = 1 and another sub-load case for LM71 or SW/0 with Max. Number of Loaded Lanes = 1.

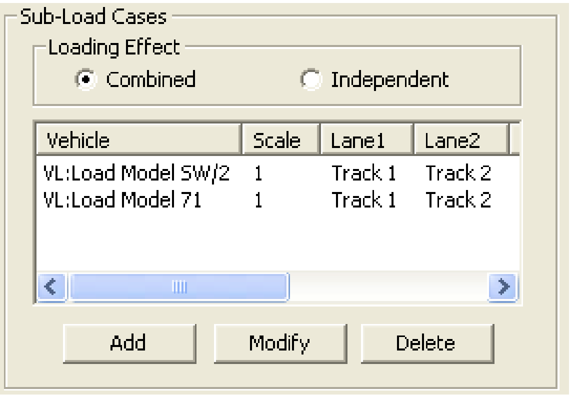
Step 1



Step 2



Step 3



Note: The 'Independent' option gives the most critical effect among two sub-load cases.

11. Application of traffic loads on railway bridges (continued)

• Load Model "unloaded train"
– any number of lengths of the uniformly distributed load qvk shall be applied to a track,
– generally Load Model "unloaded train" shall only be considered in the design of structures carrying one track.

• All continuous beam structures designed for Load Model 71 shall be checked additionally for Load Model SW/0.

• Where a dynamic analysis is required all bridges shall also be designed for the loading from Real trains and Load Model HSLM where required.

• For the verification of deformations and vibrations the vertical loading to be applied shall be:
– Load Model 71 and where required Load Models SW/0 and SW/2,
– Load Model HSLM where required,
– Real Trains when determining the dynamic behaviour in the case of resonance or excessive vibrations of the deck where required.

• For bridge decks carrying one or more tracks the checks for the limits of deflection and vibration shall be made with the number of tracks loaded with all associated relevant traffic actions. Where required classified loads shall be taken into account.

12. Groups of Loads - Characteristic values of the multicomponent action

number of tracks on structure			Groups of loads Reference EN 1991-2			Vertical forces 6.3.2/6.3.3	6.3.3	6.3.4	Horizontal forces 6.5.3	6.5.1	6.5.2	Comment
1	2	≥ 3	number of tracks loaded	Load Group[8]	Loaded track	LM 71[1] SW/0 [1], [2] HSLM[6][7]	SW/2 [1],[3]	Unloaded train	Traction, Braking [1]	Centrifugal force [1]	Nosing force [1]	
			1	gr11	T_1	1			1 [5]	0,5 [5]	0,5 [5]	Max. vertical 1 with max. longitudinal
			1	gr 12	T_1	1			0,5 [5]	1 [5]	1 [5]	Max. vertical 2 with max. transverse
			1	gr 13	T_1	1 [4]			1	0,5 [5]	0,5 [5]	Max. longitudinal
			1	gr 14	T_1	1 [4]			0,5 [5]	1	1	Max. lateral
			1	gr 15	T_1			1		1 [5]	1 [5]	Lateral stability with “unloaded train”
			1	gr 16	T_1		1		1 [5]	0,5 [5]	0,5 [5]	SW/2 with max. longitudinal
			1	gr 17	T_1		1		0,5 [5]	1 [5]	1 [5]	SW/2 with max. transverse
			2	gr 21	T_1 T_2	1 1			1 [5] 1 [5]	0,5 [5] 0,5 [5]	0,5 [5] 0,5 [5]	Max. vertical 1 with max longitudinal
			2	gr 22	T_1 T_2	1 1			0,5 [5] 0,5 [5]	1 [5] 1 [5]	1 [5] 1 [5]	Max. vertical 2 with max. transverse
			2	gr 23	T_1 T_2	1 [4] 1 [4]			1 1	0,5 [5] 0,5 [5]	0,5 [5] 0,5 [5]	Max. longitudinal
			2	gr 24	T_1 T_2	1 [4] 1 [4]			0,5 [5] 0,5 [5]	1 1	1 1	Max. lateral
			2	gr 26	T_1 T_2	 1	1 		1 [5] 1 [5]	0,5 [5] 0,5 [5]	0,5 [5] 0,5 [5]	SW/2 with max. longitudinal
			2	gr 27	T_1 T_2	 1	1 		0,5 [5] 0,5 [5]	1 [5] 1 [5]	1 [5] 1 [5]	SW/2 with max. transverse
			≥3	gr 31	T_i	0.75			0.75 [5]	0.75 [5]	0.75 [5]	Additional load case

Horizontal forces need to be separately applied by the user.

13. Load Combination

Ultimate Limit States - persistent and transient design situations

Persistent and transient design situation	Permanent actions		Prestress	Leading variable action (*)	Accompanying variable actions (*)	
	Unfavourable	Favourable			Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup} G_{kj,sup}$	$\gamma_{Gj,inf} G_{kj,inf}$	$\gamma_P P$	$\gamma_{Q,1} Q_{k,1}$		$\gamma_{Q,i} \psi_{0,i} Q_{k,i}$

$\gamma_{G,sup}$ = 1.35

γ_Q = 1.45 when *Q represents unfavorable actions due to rail traffic, for groups of loads 11 to 31 (except 16, 17, 26 and 27), load models LM71, SW/0 and HSLM and real trains, when* considered as individual leading traffic actions.

γ_Q = 1.20 when *Q represents unfavorable actions due to rail traffic, for groups of loads 16 and 17 and SW/2*

For rail traffic actions for groups of loads 26 and 27 γ_Q = 1,20 may be applied to individual components of traffic actions associated with SW/2 and γ_Q = 1,45 may be applied to individual components of traffic actions associated with load models LM71, SW/0 and HSLM, etc.

13. Load Combination (continued)

Serviceability Limit States

Combination	Permanent actions G_d		Prestress	Variable actions Q_d	
	Unfavourable	Favourable		Leading	Others
Characteristic	$G_{kj,sup}$	$G_{kj,inf}$	P	$Q_{k,1}$	$\psi_{0,i}Q_{k,i}$
Frequent	$G_{kj,sup}$	$G_{kj,inf}$	P	$\psi_{1,1}Q_{k,1}$	$\psi_{2,i}Q_{k,i}$
Quasi-permanent	$G_{kj,sup}$	$G_{kj,inf}$	P	$\psi_{2,1}Q_{k,1}$	$\psi_{2,i}Q_{k,i}$

Num of Loaded Lanes	Ψ1 Factor
1	0.8
2	0.7
3 or more	0.6

☐ Ignore Ψ1 Factor

Ψ0 is considered as 0.8 in the auto generation of load combinations.

The ψ1 factor varies depending on the number of loaded tracks, which can be considered in the moving load analysis.
The ψ0 factor does not rely on the number of loaded tracks, which can be considered in the Load Combination.

13. Load Combination (continued)

Actions			ψ_0	ψ_1	ψ_2 [4)]
	gr11 (LM71 + SW/0)	Max. vertical 1 with max. longitudinal			
	gr12 (LM71 + SW/0)	Max. vertical 2 with max. transverse			
	gr13 (Braking/traction)	Max. longitudinal			
	gr14 (Centrifugal/nosing)	Max. lateral	0,80	0,80	0
	gr15 (Unloaded train)	Lateral stability with "unloaded train"			
	gr16 (SW/2)	SW/2 with max. longitudinal			
Main traffic actions (groups of loads)	gr17 (SW/2)	SW/2 with max. transverse			
	gr21 (LM71 + SW/0)	Max. vertical 1 with max. longitudinal			
	gr22 (LM71 + SW/0)	Max. vertical 2 with max transverse			
	gr23 (Braking/traction)	Max. longitudinal	0,80	0,70	0
	gr24 (Centrifugal/nosing)	Max. lateral			
	gr26 (SW/2)	SW/2 with max. longitudinal			
	gr27 (SW2)	SW/2 with max. transverse			
	gr31 (LM71 + SW/0)	Additional load cases	0,80	0,60	0

14. Traffic loads for fatigue

1) For normal traffic based on characteristic values of Load Model 71, including the dynamic factor , the fatigue assessment should be carried out on the basis of the traffic mixes, "standard traffic", "traffic with 250 kN-axles" or “light traffic mix” depending on whether the structure carries mixed traffic, predominantly heavy freight traffic or lightweight passenger traffic in accordance with the requirements specified.

2) Each of the mixes is based on an annual traffic tonnage of 25×10^6 ton passing over the bridge on each track.

3) For structures carrying multiple tracks, the fatigue loading shall be applied to a maximum of two tracks in the most unfavorable positions.

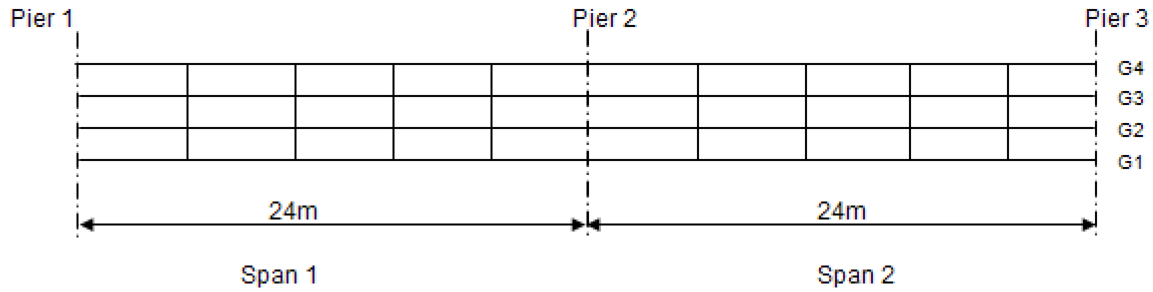
4) The fatigue damage should be assessed over the design working life. 100 years is recommended.

5) Vertical rail traffic actions including dynamic effects and centrifugal forces should be taken into account in the fatigue assessment. Generally nosing and longitudinal traffic actions may be neglected in the fatigue assessment.

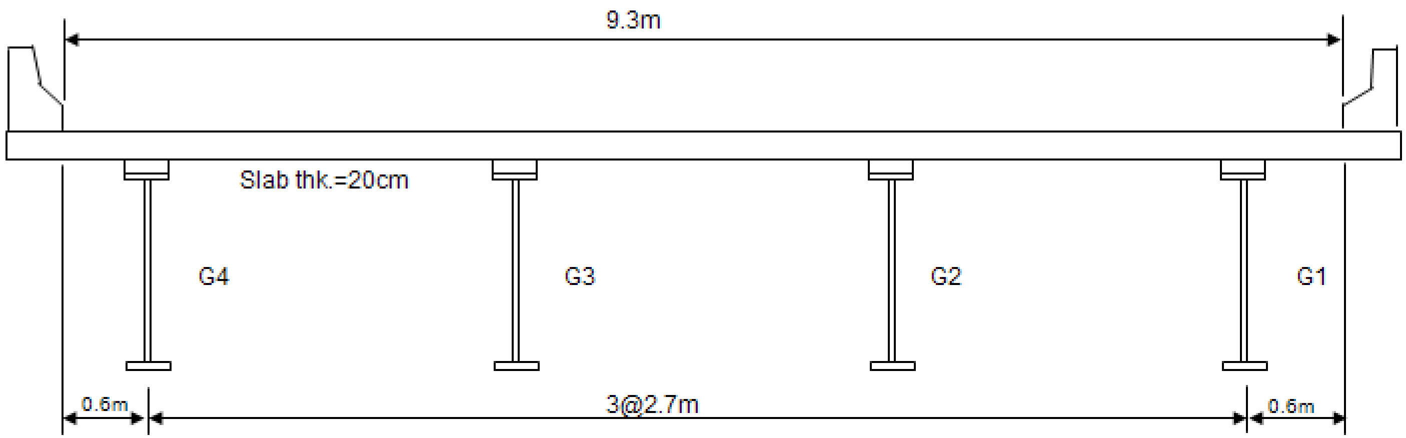
Part 2. Tutorial

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

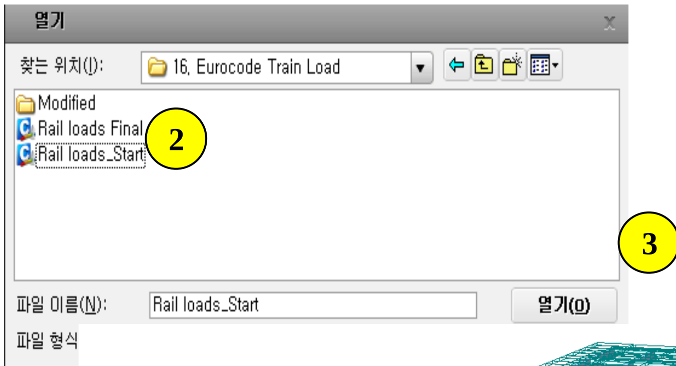
2. Number and track gage of notional tracks

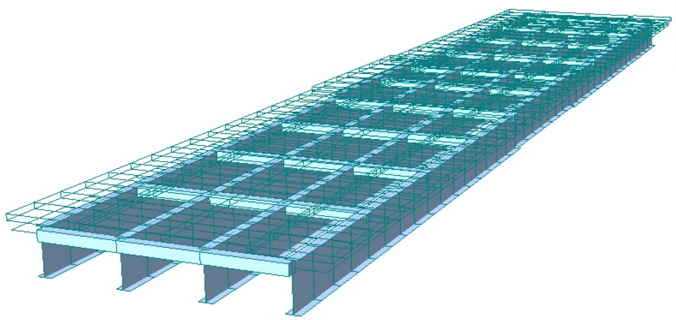
Carriageway width	Number of notional tracks	Track gage Center to center
9.3 m	$n_1 = 2$	*1.5 m*

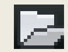
3. Moving Load Cases

No	Moving Load Case	Rail Traffic Load	Load Combination	ψ1	γQ
1	LM71_ULS	Load Model 71	ULS	N/A	1.45
2	LM71_SLS C		SLS-Characteristic	N/A	N/A
3	LM71_SLS F		SLS-Frequent	0.8 one track loaded 0.7 two tracks loaded	N/A
4	SW/0_ULS	Load Model SW/0	ULS	N/A	1.45
5	SW/0_SLS C		SLS-Characteristic	N/A	N/A
6	SW/0_SLS F		SLS-Frequent	0.8 one track loaded 0.7 two tracks loaded	N/A
7	SW/2+LM71_ULS	Load Model SW/2 Load Model 71	ULS	N/A	1.2 SW/2 1.45 LM71
8	SW/2+LM71_SLS C		SLS-Characteristic	N/A	N/A
9	SW/2+LM71_SLS F		SLS-Frequent	0.8 one track loaded 0.7 two tracks loaded	N/A
10	SW/2+SW/0_ULS	Load Model SW/2 Load Model SW/0	ULS	N/A	1.2 SW/2 1.45 LM71
11	SW/2+SW/0_SLS C		SLS-Characteristic	N/A	N/A
12	SW/2+SW/0_SLS F		SLS-Frequent	0.8 one track loaded 0.7 two tracks loaded	N/A

Step 1. Open the model file.

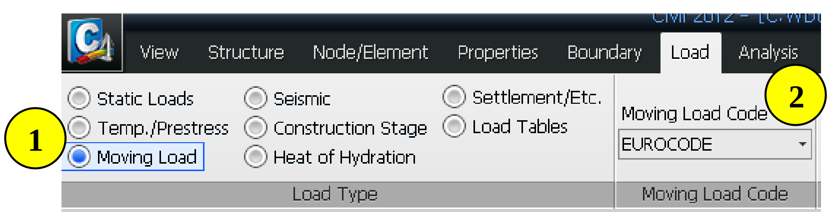




1. Click  .
2. Select ‘*Rail Loads_Start*’.
3. Click **[Open]** button.

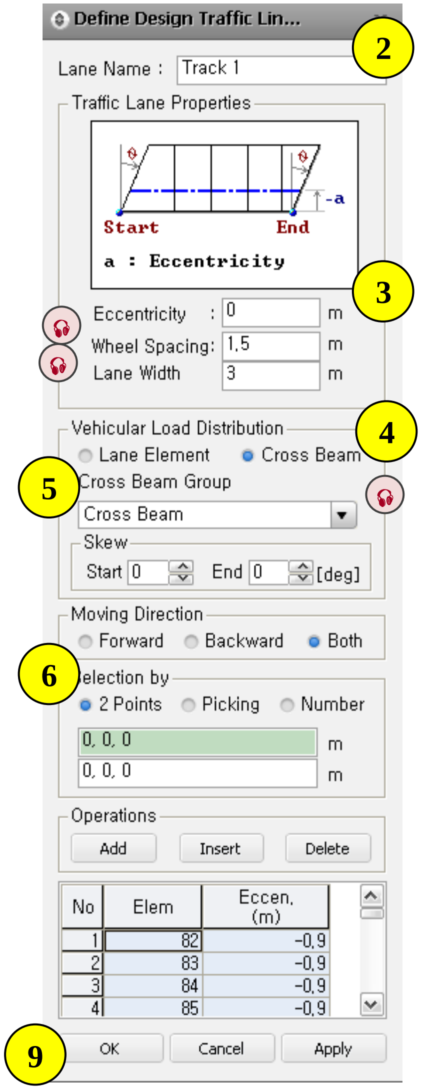
This tutorial is intended to introduce the functions of Moving load analysis. Therefore the procedures of creating elements, assigning static loads and boundary conditions are omitted here. Refer to the online manual for the detailed usage.

Step 2. Define moving load code



1. **Load > Moving Load > Moving Load Code**
2. Moving Load Code: **EUROCODE**

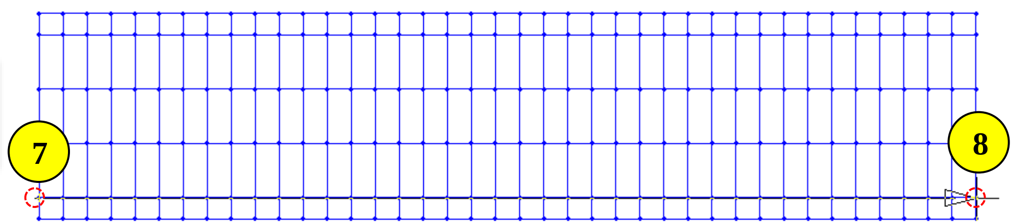
Step 3-1. Define Traffic Line Lane (Track 1)



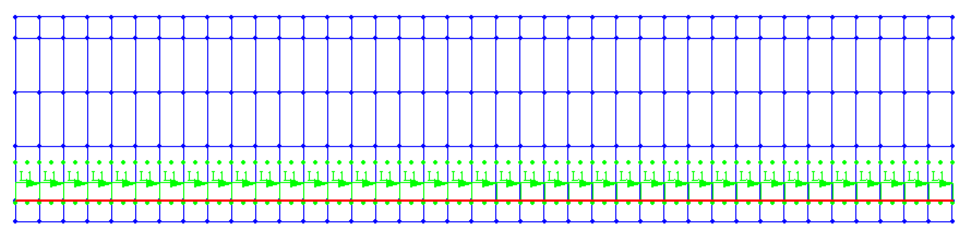
1. **Load > Moving Load > Traffic Line Lanes > Add**
2. Lane Name: **Track 1**
3. Eccentricity : **-0.9 m,** Wheel Spacing: **1.5m**
4. Vehicular Load Distribution : **Cross Beam**
5. Cross Beam Group: **Cross Beam**
6. Selection by : **2 Points**
7. Click **(0,0,0).**
8. Click **(48,0,0).**
9. Click **[OK]** button.

Wheel Spacing represents the center-to-center distance of track gage.

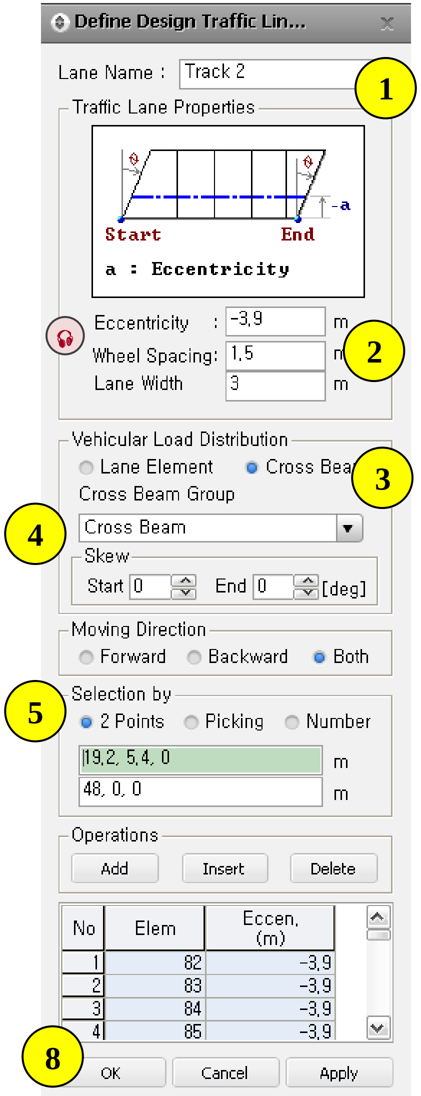
Lane Width is not used in the analysis.



Cross Beam group comprises of all the transverse elements.



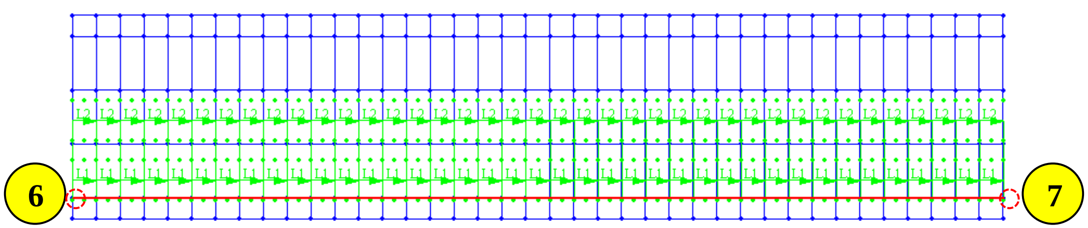
Step 3-2. Define Traffic Line Lane (Track 2)



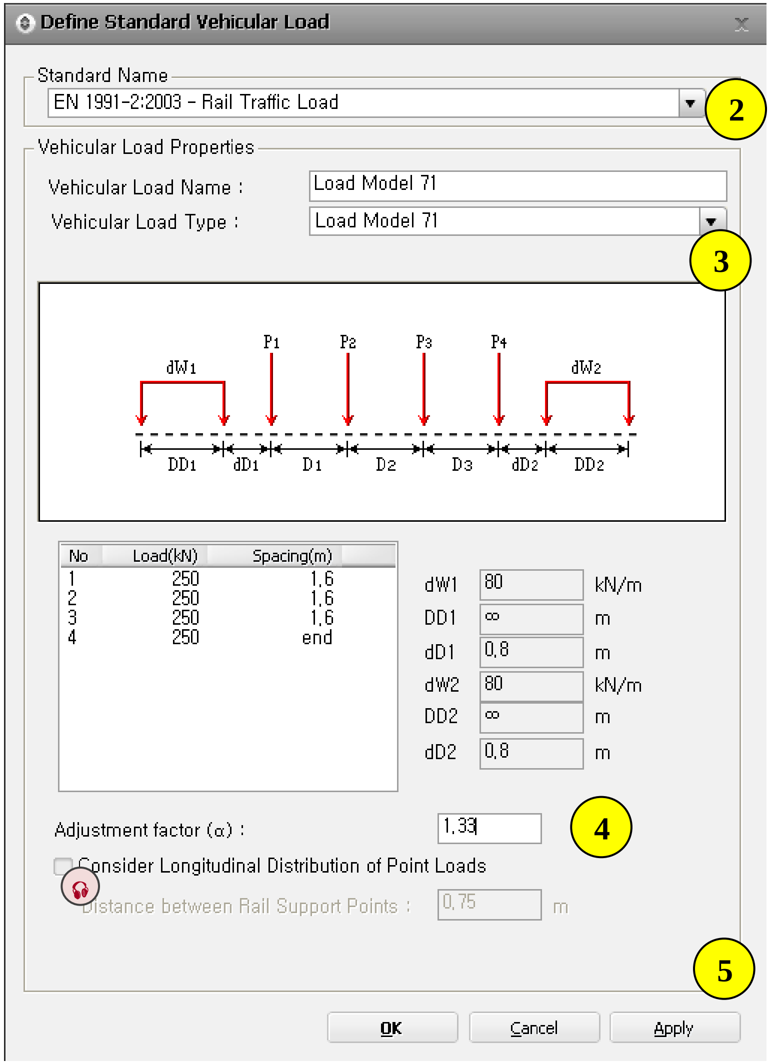
1. Lane Name: **Track 2**
2. Eccentricity : **-3.9 m,** Wheel Spacing: **1.5m**
3. Vehicular Load Distribution : **Cross Beam**
4. Cross Beam Group: **Cross Beam**
5. Selection by : **2 Points**
6. Click **(0,0,0).**
7. Click **(48,0,0).**
8. Click **[OK]** button.

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.

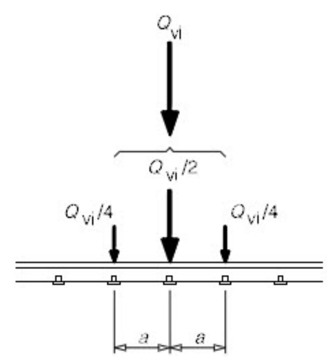


Step 4-1. Define Rail Traffic Loads (Load Model 71)

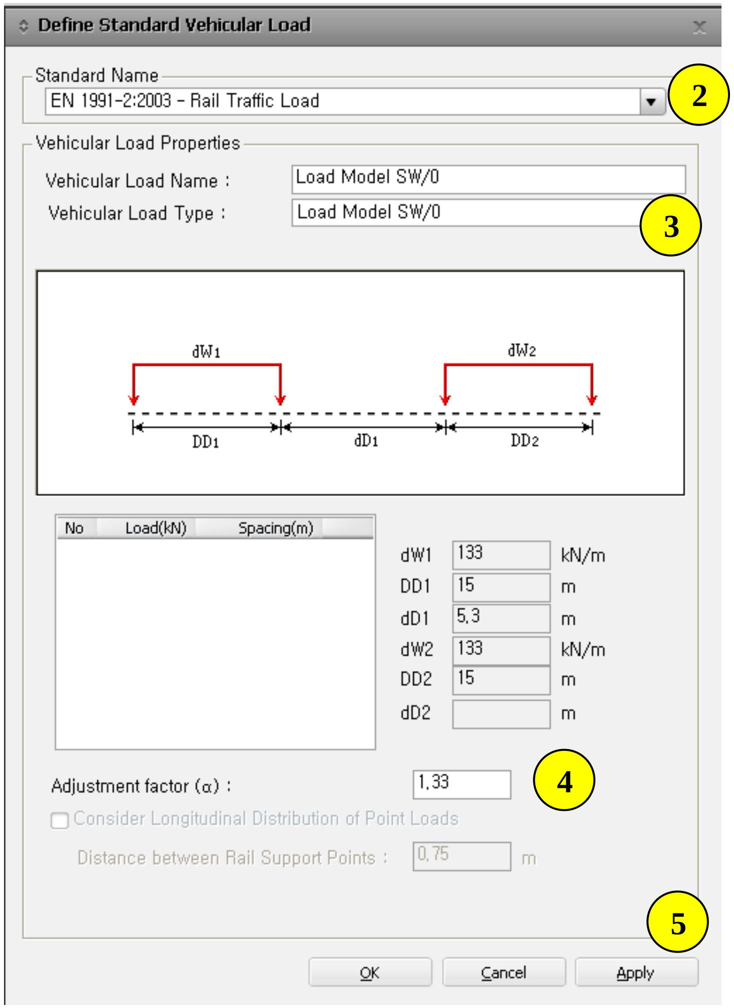


1. ***Load > Moving Load > Vehicles > Add Standard***
2. *Standard Name :* ***EN 1991-2:2003 – Rail Traffic Load***
3. *Vehicular Load Type :* ***Load Model 71***
4. *Adjustment factor (α):* ***1.33***
5. *Click* **[Apply]** *button.*

A point force in Load Model 71 and HSLM A(A1 to A10) may be distributed over three rail support points as shown below:

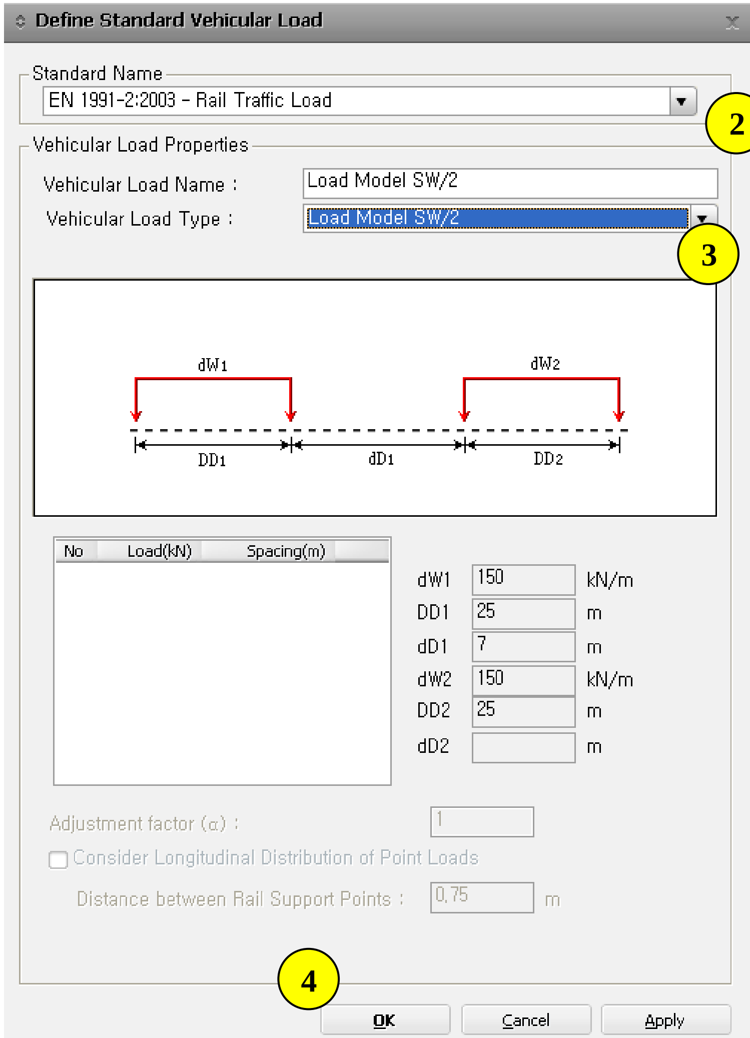


Step 4-2. Define Rail Traffic Loads (Load Model SW/0)



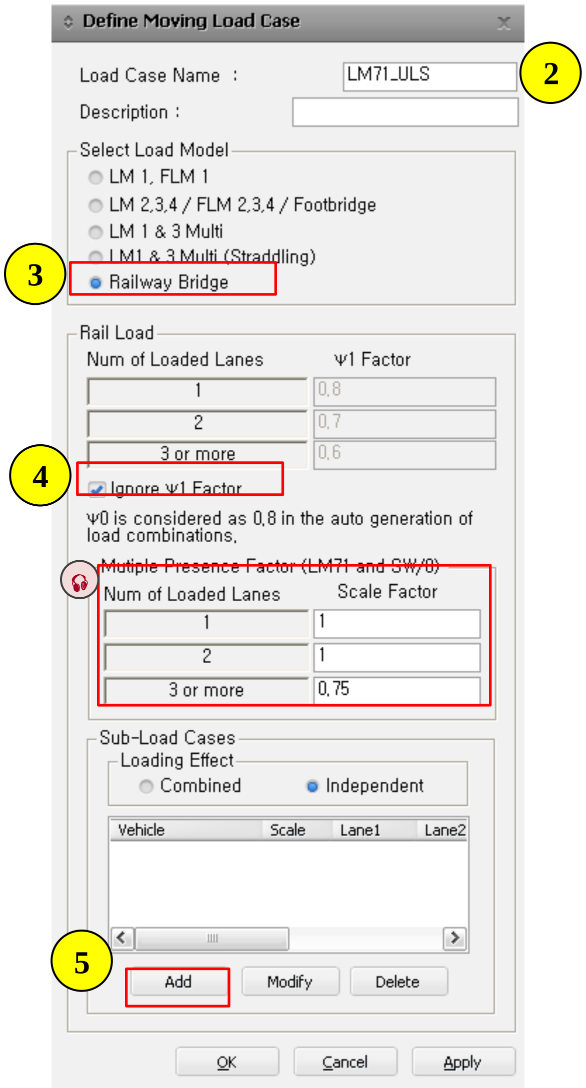
1. ***Load > Moving Load > Vehicles***
2. *Standard Name :* ***EN 1991-2:2003 – Rail Traffic Load***
3. *Vehicular Load Type :* ***Load Model SW/0***
4. *Adjustment factor (α):* ***1.33***
5. *Click* **[Apply]** *button.*

Step 4-3. Define Rail Traffic Loads (Load Model SW/2)



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

Step 5-1. Define Moving Load Case - LM71 ULS



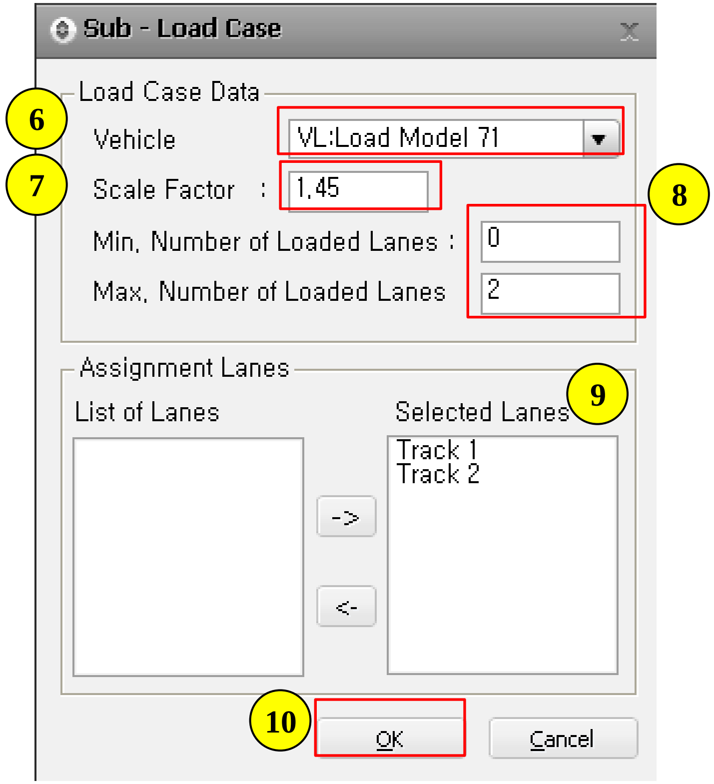
1. *Load > **Moving Load > Moving Load Cases > Add***
2. *Load Case Name: **LM71_ULS***
3. *Select Load Model : **Railway Bridge***
4. *Check on the '**Ignore ψ1 factor**' option.*
5. *Press [ADD].*

To be continued…

*The ψ1 factor is not applied to the results by checking on the **Ignore ψ1 Factor** option. This load case will be used for the ULS combination.*

For the determination of the most adverse load effects from the application of Load Model 71 and SW/0, these load models shall be applied to any one track, any two tracks or 0.75 times the load model to three or more tracks.

Step 5-1. Define Moving Load Case – LM71 ULS (continued)



6. Select the **VL: Load Model 71**

7. Scale Factor: **1.45**

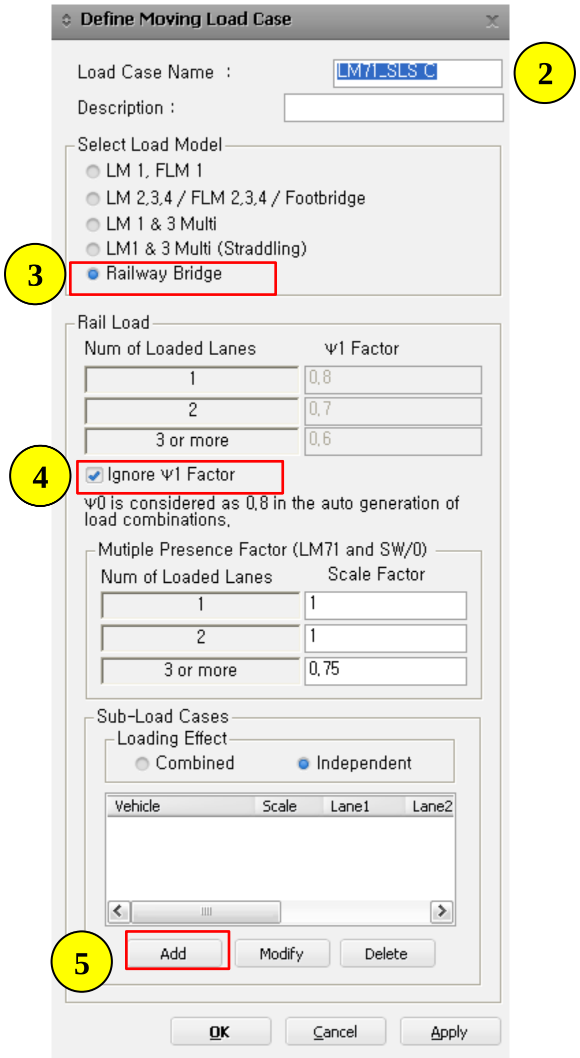
8. Specify the Min. no of lanes = **0** and Max. no of lanes = **2**.

9.Select the Lanes **Track 1** and **Track 2** from the list of lanes.

10.Press [OK].

- *Load factor γ_Q to be used for the ULS combination may be applied to the Moving Load Case or to the Combination. In this example, the load factor γ_Q is applied to the load case for all the moving load cases and the factor will not be considered in the ULS combination.*
- *The load factors γ_Q are 1.45 for LM71 and 1.2 for SW/2 . These different values cannot be considered in Load Combination in the program. Therefore, these factors should be entered in the Moving Load Case by using Scale Factor.*

Step 5-2. Define Moving Load Case - LM71 SLS C

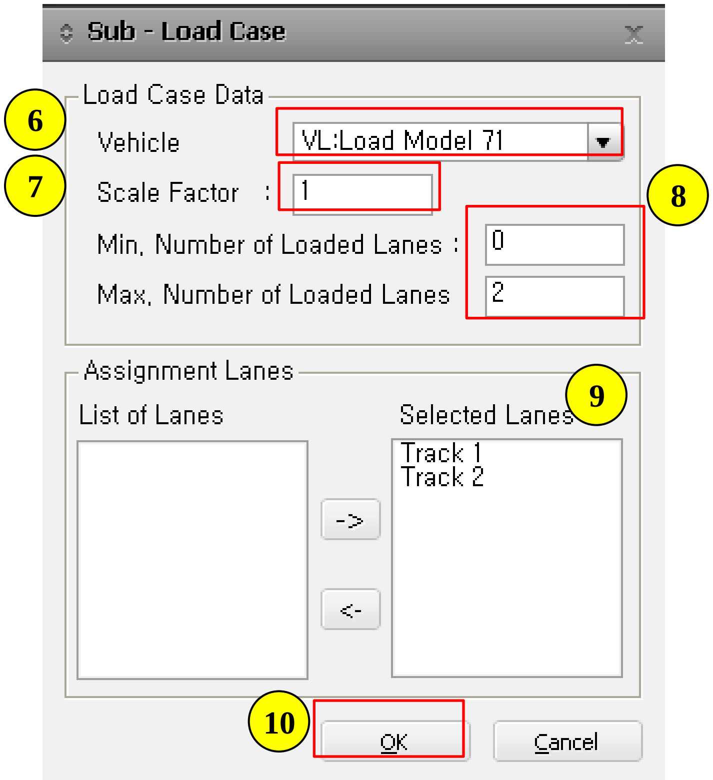


1. *Load* > ***Moving Load*** > ***Moving Load Cases*** > ***Add***
2. *Load Case Name:* ***LM71_SLS C***
3. *Select Load Model :* ***Railway Bridge***
4. *Check on the '**Ignore ψ1 factor**' option.*
5. *Press [ADD].*

To be continued…

The ψ1 factor is ignored because this load case will be used for the SLS characteristic combination.

Step 5-2. Define Moving Load Case – LM71 SLS C (continued)



*6. Select the **VL: Load Model 71***

*7. Scale Factor: **1.0***

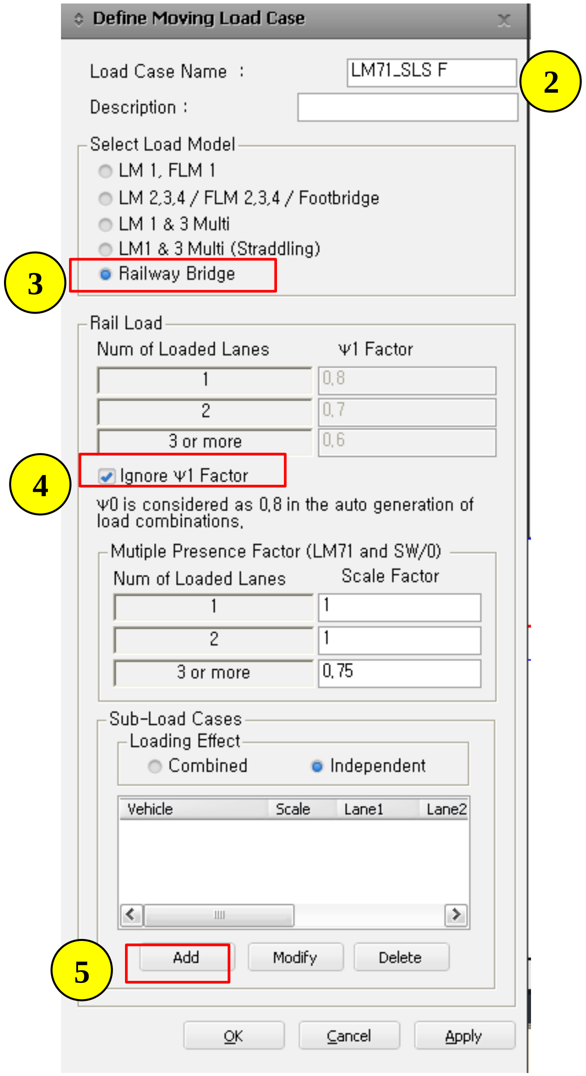
*8. Specify the Min. no of lanes = **0** and Max. no of lanes = **2**.*

*9.Select the Lanes **Track 1** and **Track 2** from the list of lanes.*

10.Press [OK].

Scale Factor is set to 1.0 because this load case will be used for SLS characteristic combination.

Step 5-3. Define Moving Load Case - LM71 SLS F

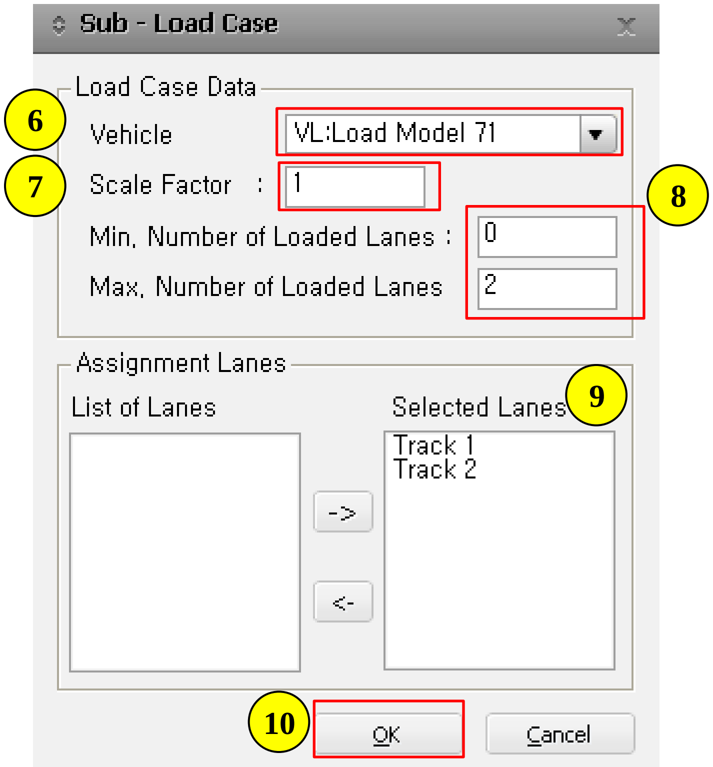


1. ***Load > Moving Load > Moving Load Cases > Add***
2. *Load Case Name: **LM71_SLS F***
3. *Select Load Model : **Railway Bridge***
4. *Check off the '**Ignore ψ1 factor**' option.*
5. *Press [ADD].*

To be continued…

- *The ψ1 factor is applied to the results by checking off the **Ignore ψ1 Factor** option. This load case will be used for the SLS frequent combination.*
- *The ψ1 factor can take value as 0.8, 0.7 or 0.6 depending on the number of loaded tracks. For the number of loaded tracks greater than 3, a value of ψ1=0.6 is applied. The ψ1 value is reflected on the vehicle loads while ψ0 value is reflected when the load combination s are generated using **Auto Generation** function.*

Step 5-3. Define Moving Load Case – LM71 SLS F (continued)



*6. Select the **VL: Load Model 71***

*7. Scale Factor: **1.0***

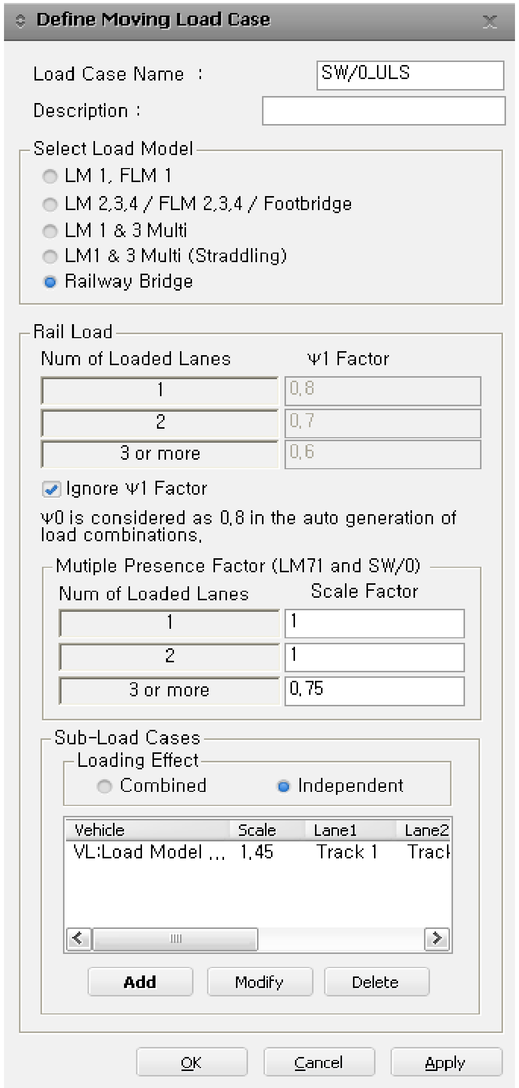
*8. Specify the Min. no of lanes = **0** and Max. no of lanes = **2**.*

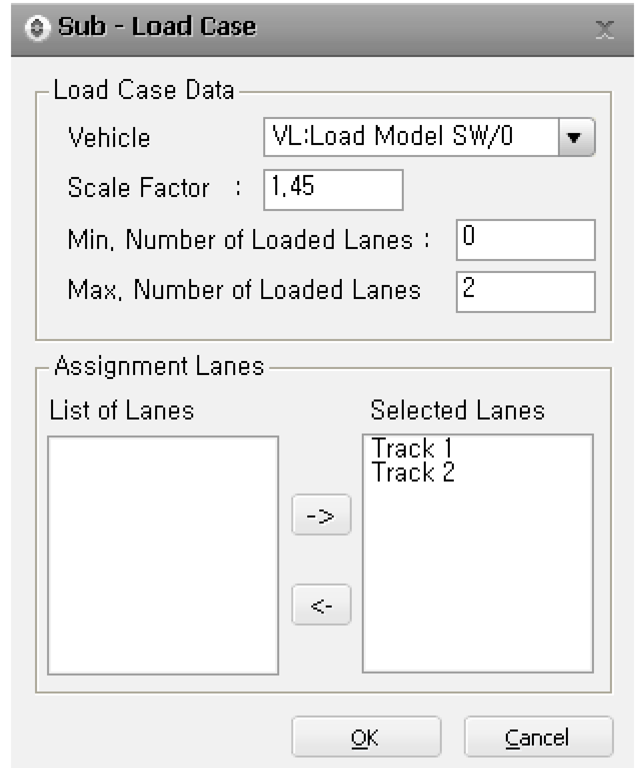
*9.Select the Lanes **Track 1** and **Track 2** from the list of lanes.*

10.Press [OK].

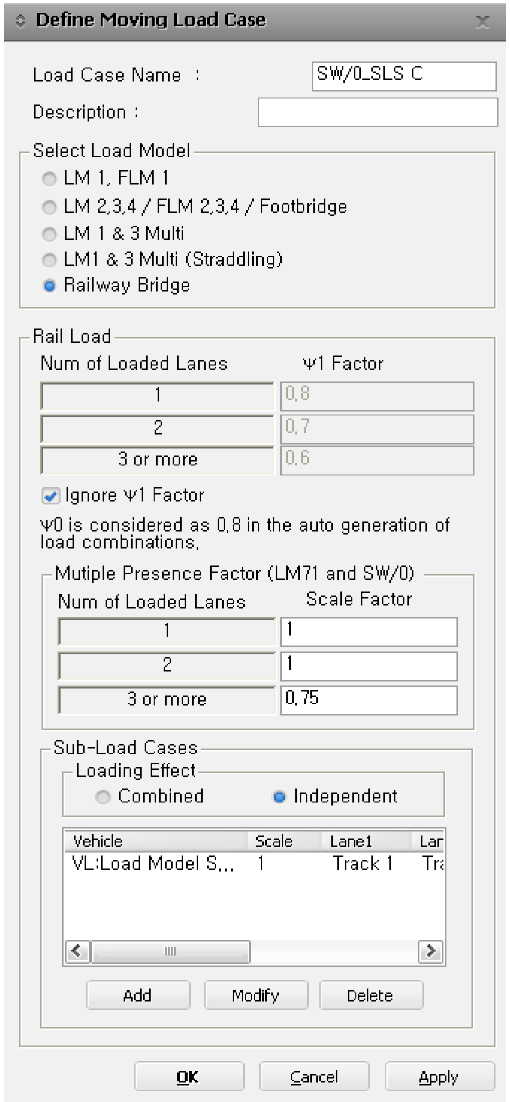
Scale Factor is set to 1.0 because this load case will be used for SLS frequent combination.

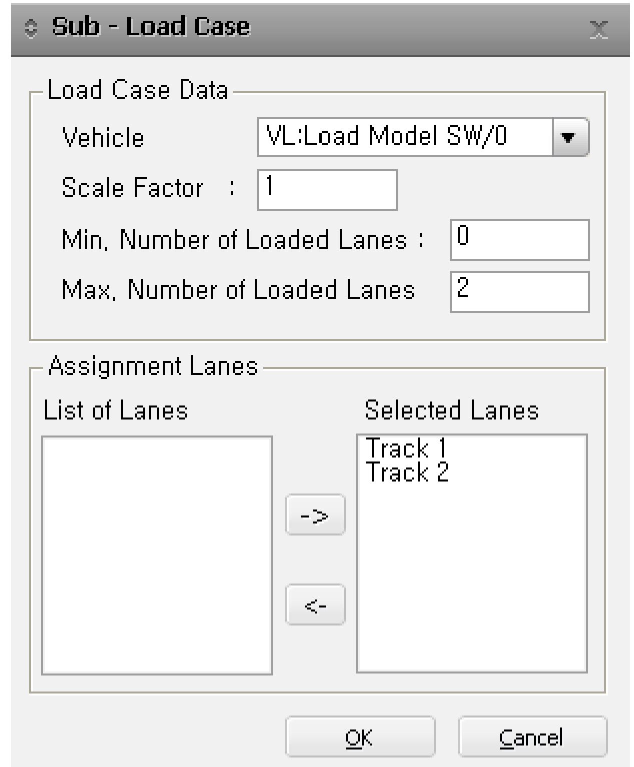
Step 5-4. Define Moving Load Case – SW/0 ULS



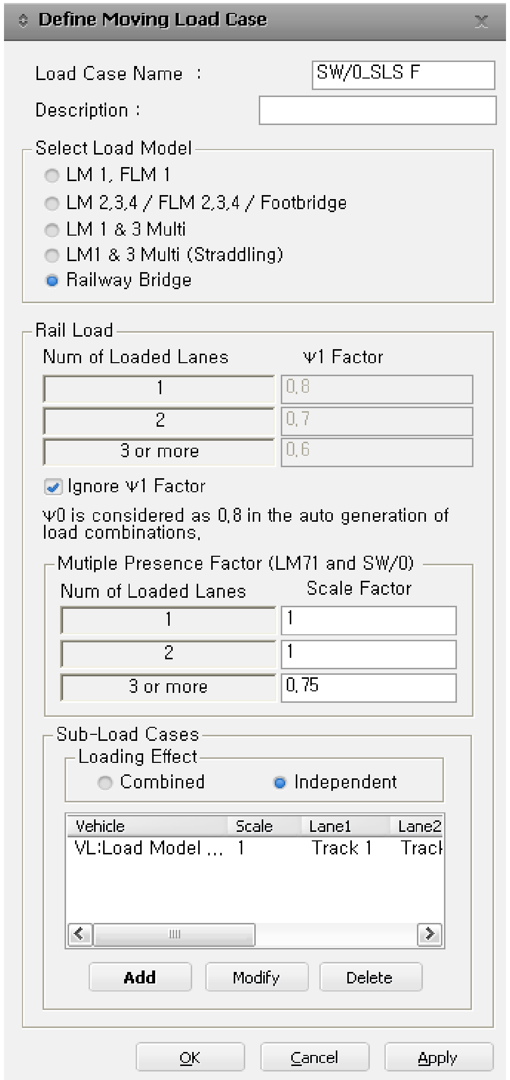


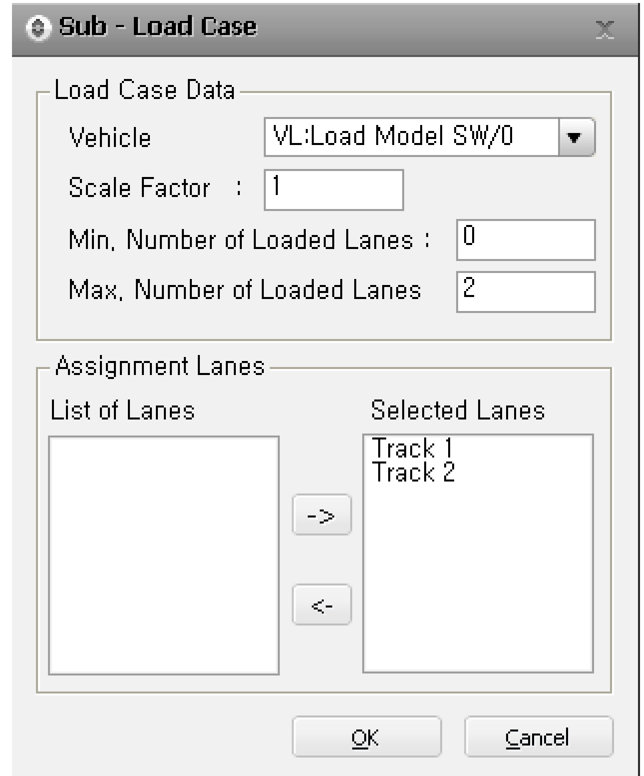
Step 5-5. Define Moving Load Case – SW/0 SLS C



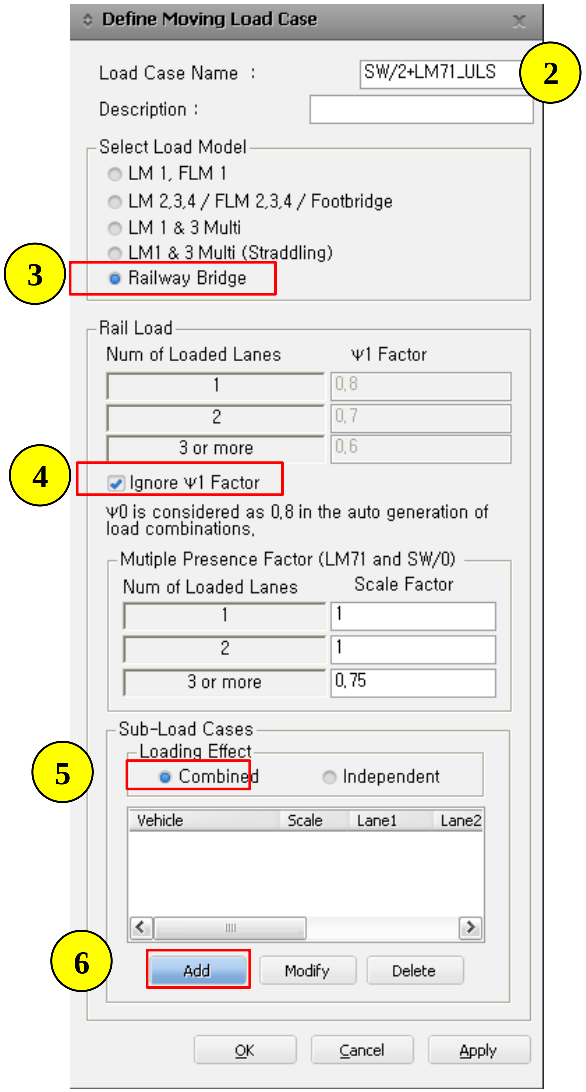


Step 5-6. Define Moving Load Case – SW/0 SLS F





Step 5-7. Define Moving Load Case – SW/2+LM71 ULS

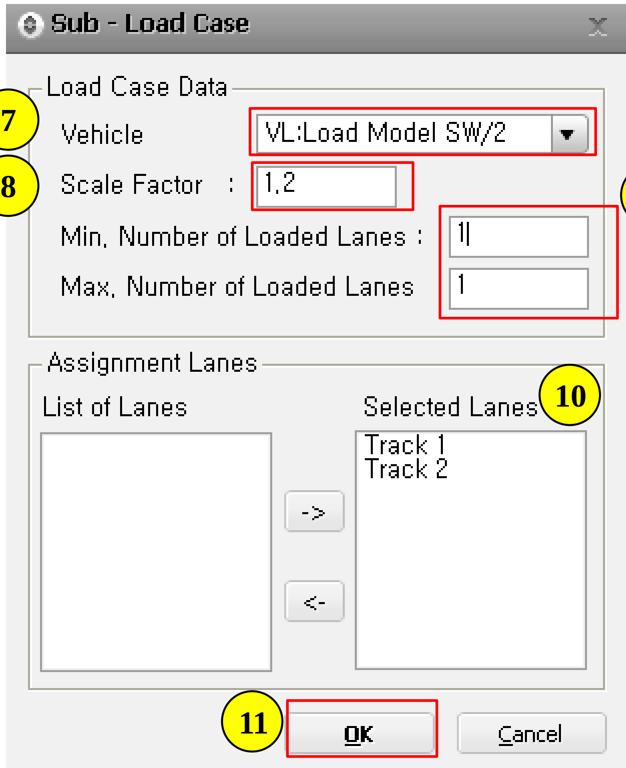


1. ***Load* > *Moving Load* > *Moving Load Cases* > *Add***
2. *Load Case Name:* ***SW/2+LM71_ULS***
3. *Select Load Model :* ***Railway Bridge***
4. *Check on the '**Ignore ψ1 factor**' option.*
5. *Select '**Combined**' for loading effect.*
6. *Press [ADD].*

To be continued…

*Two sub-load cases will be defined, one for SW/2 and another for LM71. By selecting **Combined** option, the loading condition in which SW/2 and LM71 are applied at the same time can be considered. The **Independent** option does not consider two different load models applied at the same time. The **Independent** option tries one load model at a time and finds the most adverse condition.*

Step 5-7. Define Moving Load Case – SW/2+LM71 ULS (continued)



*7. Select the **VL: Load Model SW/2***

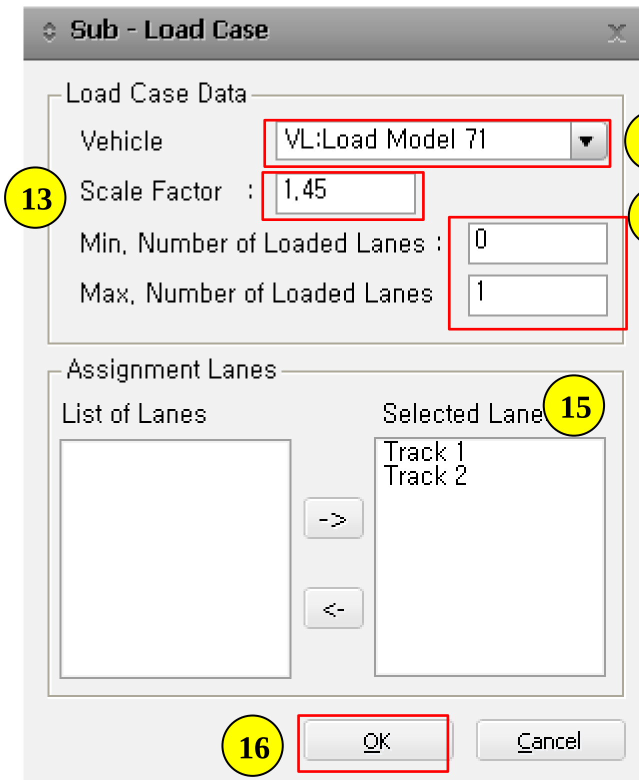
*8. Scale Factor: **1.2***

*9. Specify the Min. no of lanes = **1** and Max. no of lanes = **1**.*

*10.Select the Lanes **Track 1** and **Track 2** from the list of lanes.*

11.Press [OK].

Different load factor γ_Q can be applied to each load model.



*12. Select the **VL: Load Model 71***

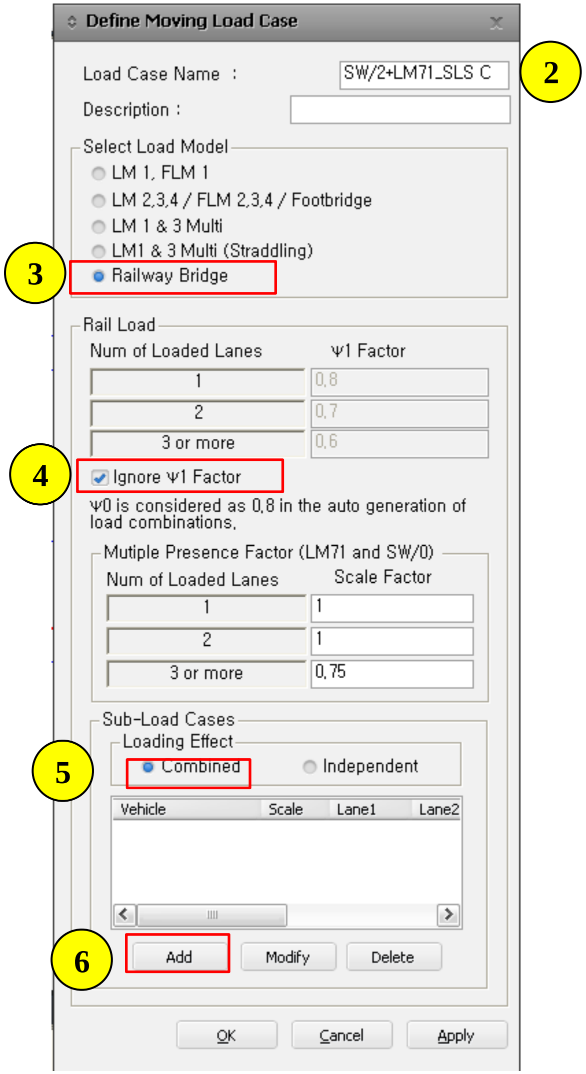
*13. Scale Factor: **1.45***

*14. Specify the Min. no of lanes = **0** and Max. no of lanes = **1**.*

*15.Select the Lanes **Track 1** and **Track 2** from the list of lanes.*

16.Press [OK].

Step 5-8. Define Moving Load Case – SW/2+LM71 SLS C

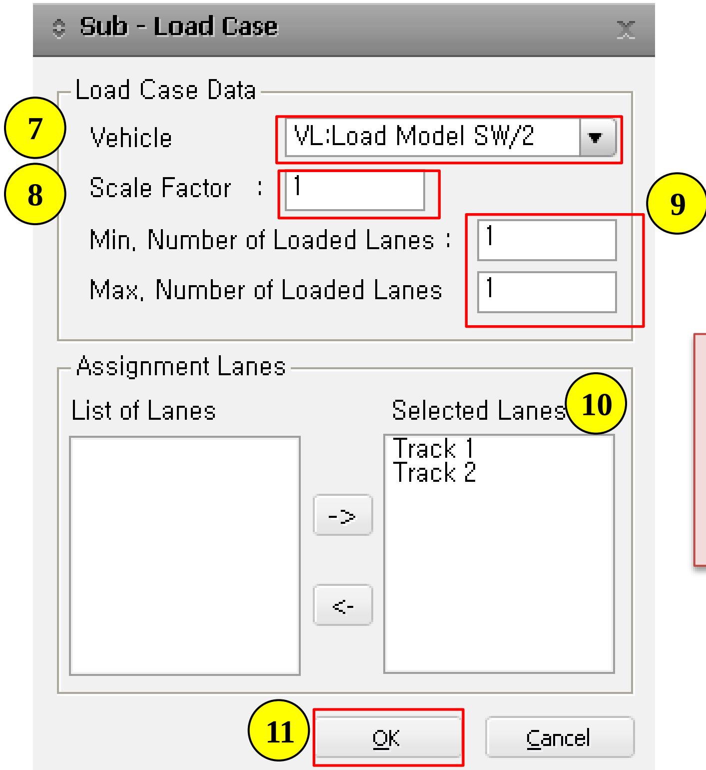


1. ***Load > Moving Load > Moving Load Cases > Add***
2. *Load Case Name:* ***SW/2+LM71_SLS C***
3. *Select Load Model :* ***Railway Bridge***
4. *Check on the '**Ignore ψ1 factor**' option.*
5. *Select '**Combined**' for loading effect.*
6. *Press [ADD].*

To be continued…

The ψ1 factor is ignored because this load case will be used for the SLS characteristic combination.

Step 5-8. Define Moving Load Case – SW/2+LM71 SLS C (continued)



7. Select the ***VL: Load Model SW/2***

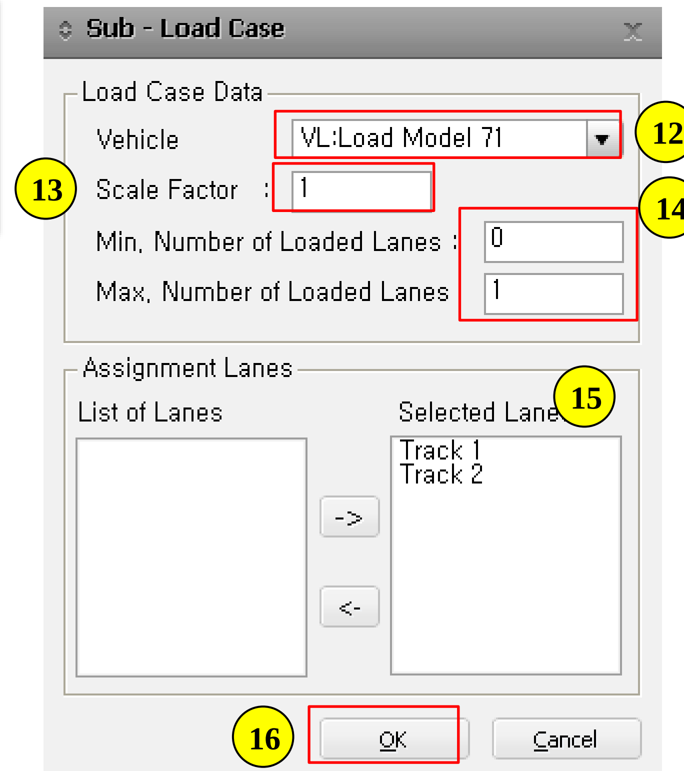
8. *Scale Factor:* ***1.0***

9. *Specify the Min. no of lanes =* ***1*** *and Max. no of lanes =* ***1****.*

10. *Select the Lanes* ***Track 1*** *and* ***Track 2*** *from the list of lanes.*

11. *Press [OK].*

Scale Factor is set to 1.0 because this load case will be used for SLS characteristic combination.



12. *Select the* ***VL: Load Model 71***

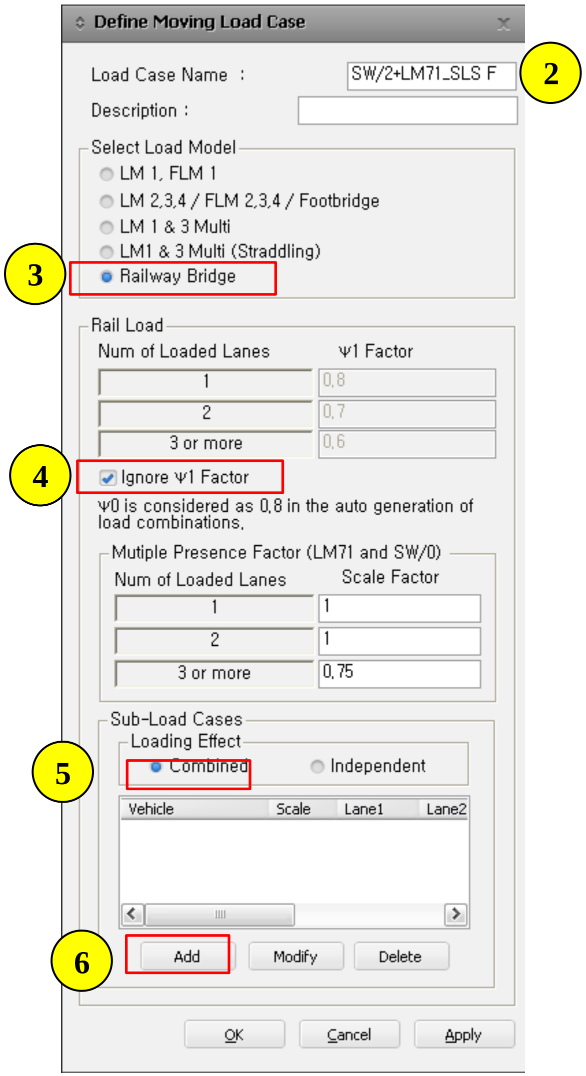
13. *Scale Factor:* ***1.0***

14. *Specify the Min. no of lanes =* ***0*** *and Max. no of lanes =* ***1****.*

15. *Select the Lanes* ***Track 1*** *and* ***Track 2*** *from the list of lanes.*

16. *Press [OK].*

Step 5-9. Define Moving Load Case – SW/2+LM71 SLS F

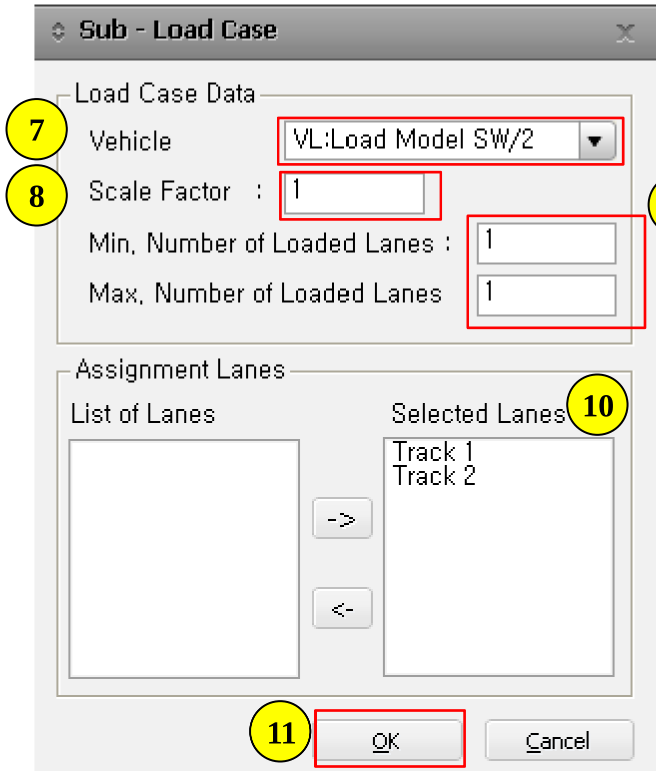


1. ***Load*** > ***Moving Load*** > ***Moving Load Cases*** > ***Add***
2. *Load Case Name:* ***SW/2+LM71_SLS F***
3. *Select Load Model :* ***Railway Bridge***
4. *Check off the '**Ignore ψ1 factor**' option.*
5. *Select '**Combined**' for loading effect.*
6. *Press [ADD].*

To be continued…

*The ψ1 factor is applied to the results by checking off the **Ignore ψ1 factor** option. This load case will be used for the SLS frequent combination.*

Step 5-9. Define Moving Load Case – SW/2+LM71 SLS F (continued)



*7. Select the **VL: Load Model SW/2***

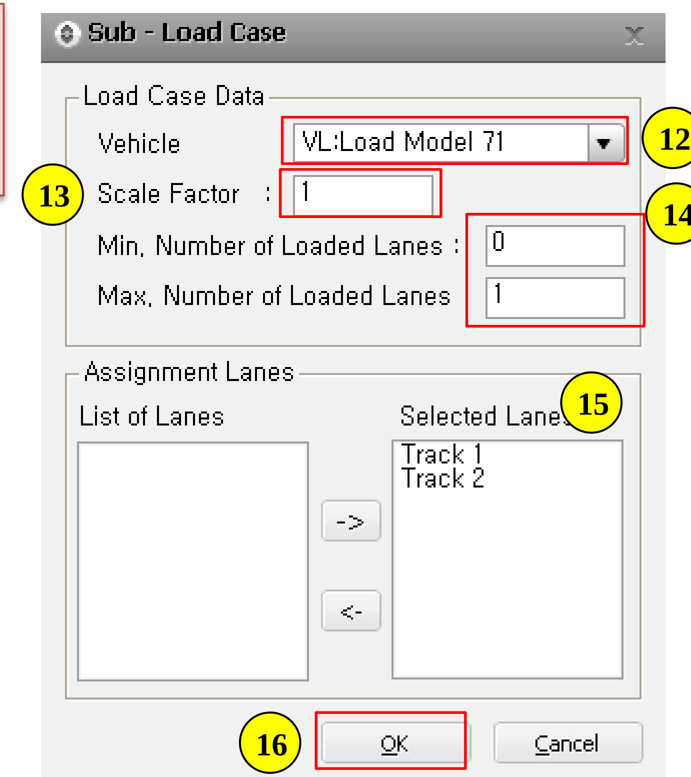
*8. Scale Factor: **1.0***

*9. Specify the Min. no of lanes = **1** and Max. no of lanes = **1**.*

*10.Select the Lanes **Track 1** and **Track 2** from the list of lanes.*

11.Press [OK].

Scale Factor is set to 1.0 because this load case will be used for SLS frequent combination.



*12. Select the **VL: Load Model 71***

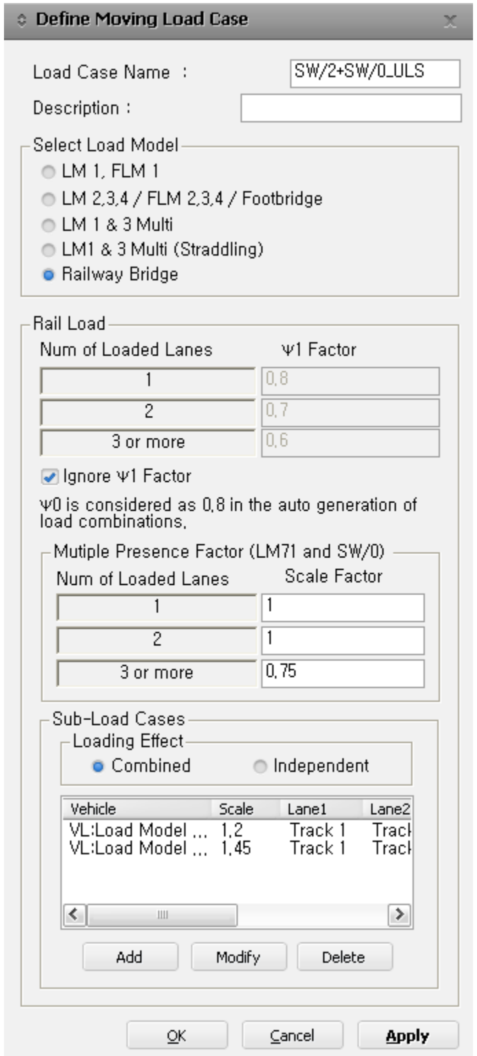
*13. Scale Factor: **1.0***

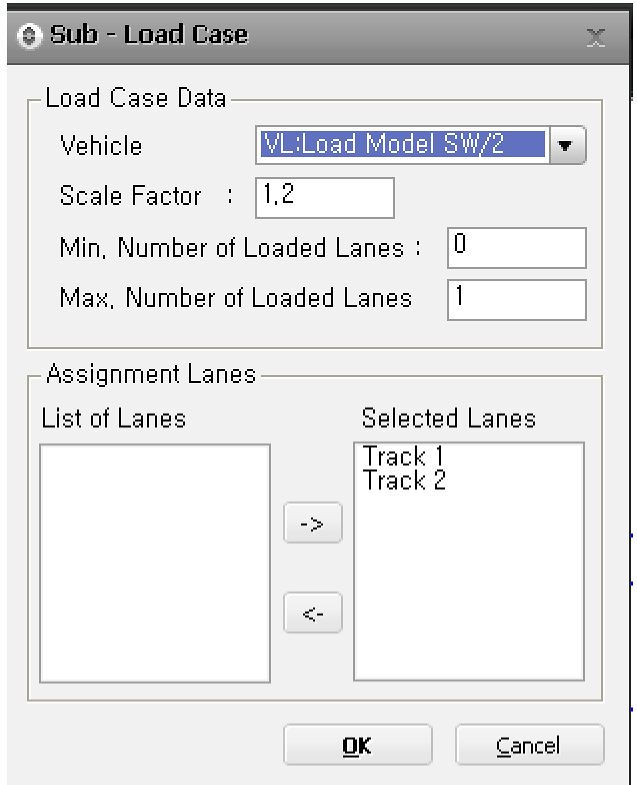
*14. Specify the Min. no of lanes = **0** and Max. no of lanes = **1**.*

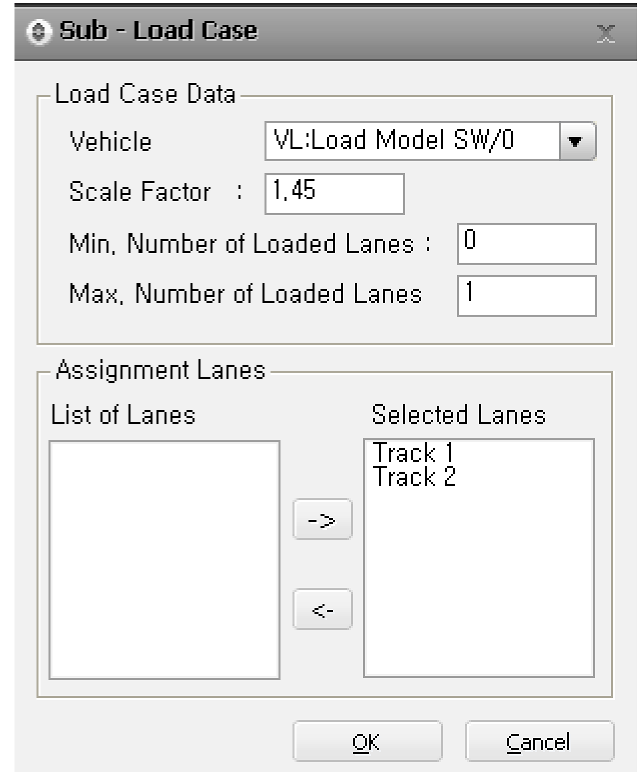
*15.Select the Lanes **Track 1** and **Track 2** from the list of lanes.*

16.Press [OK].

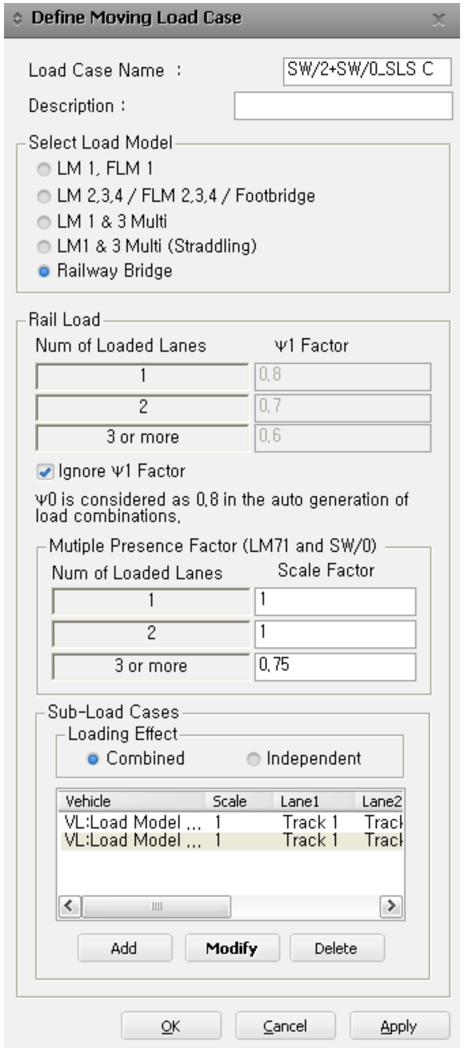
Step 5-10. Define Moving Load Case – SW/2+SW/0 ULS

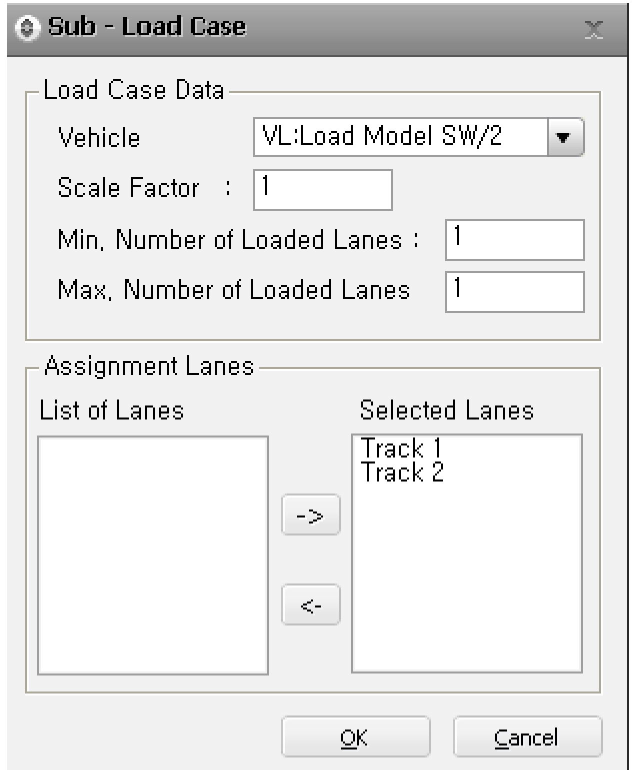


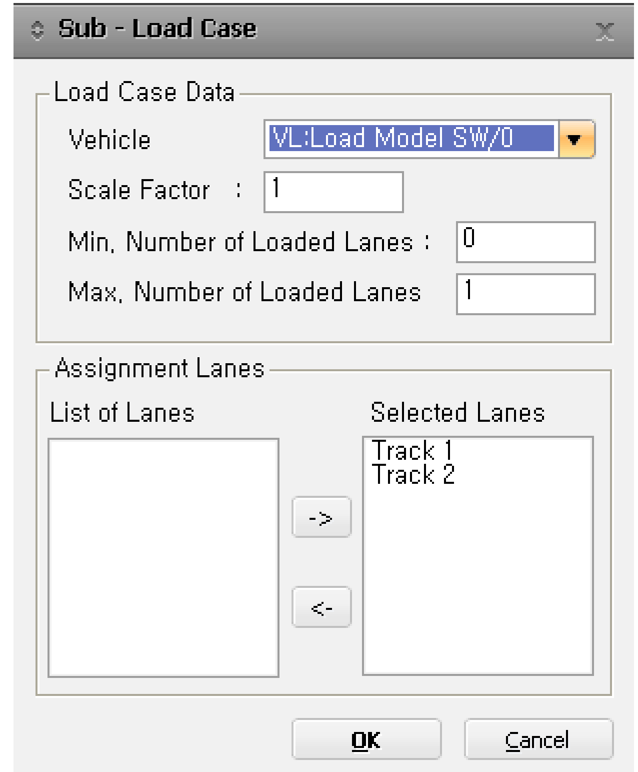




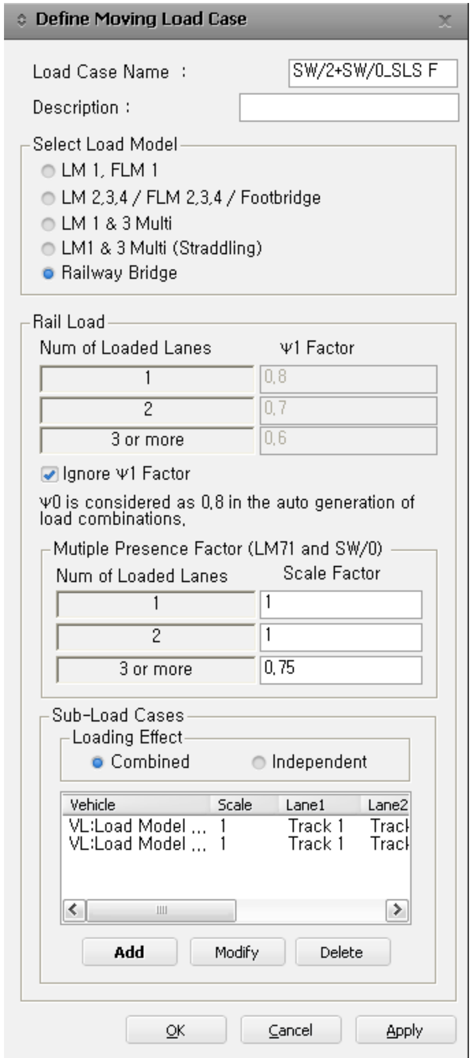
Step 5-11. Define Moving Load Case – SW/2+SW/0 SLS C

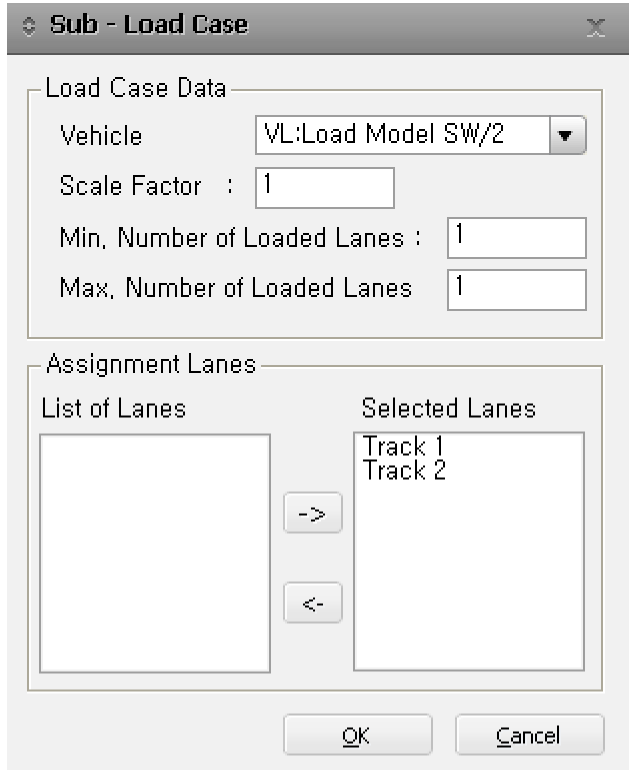


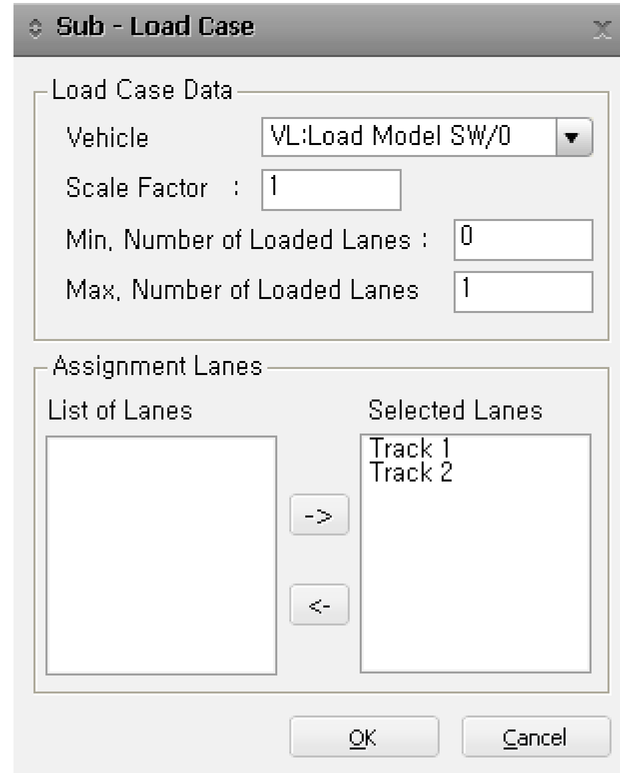




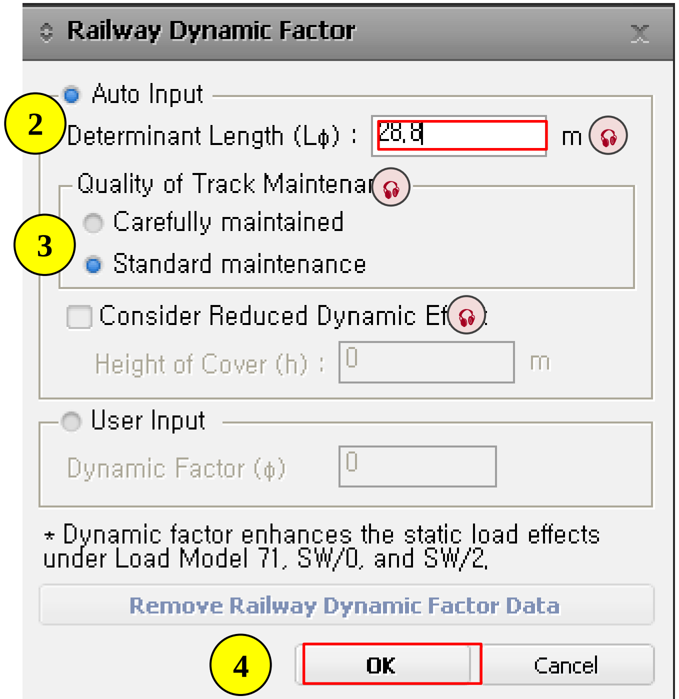
Step 5-12. Define Moving Load Case – SW/2+SW/0 SLS F







Step 6-1. Railway Dynamic Factor



1. *Load > Moving Load > Railway Dynamic Factor*
2. *Determinant Length: **28.8m***
3. *Quality of the Track Maintenance: **Standard maintenance***
4. *Press [OK].*

*This factor amplifies all the results based on the dynamic factor calculation which will be dependent on the determinant length specified by the user. After the application of the global dynamic factor, element specific dynamic factors can be applied to individual elements using the **Railway Dynamic Factor by Element** function in order to consider different determinant lengths for different elements.*

Based on the quality of track maintenance the program calculates the value of Dynamic Factor based on the following formulae:

(a) For carefully maintained track:

$$\Phi_2 = \frac{1,44}{\sqrt{L_\Phi} - 0,2} + 0,82$$

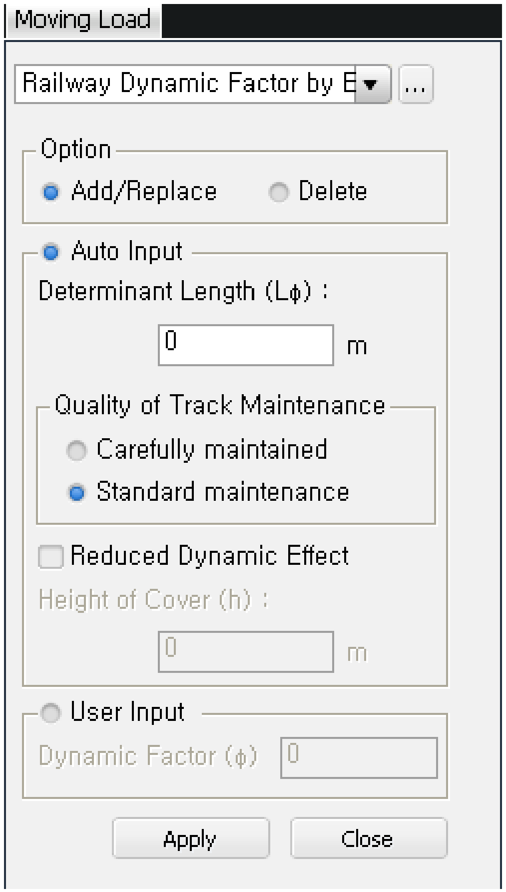
(b) For track with standard maintenance:

$$\Phi_3 = \frac{2,16}{\sqrt{L_\Phi} - 0,2} + 0,73$$

A reduced value of Dynamic factor can be used for concrete bridges having cover > 1.0m

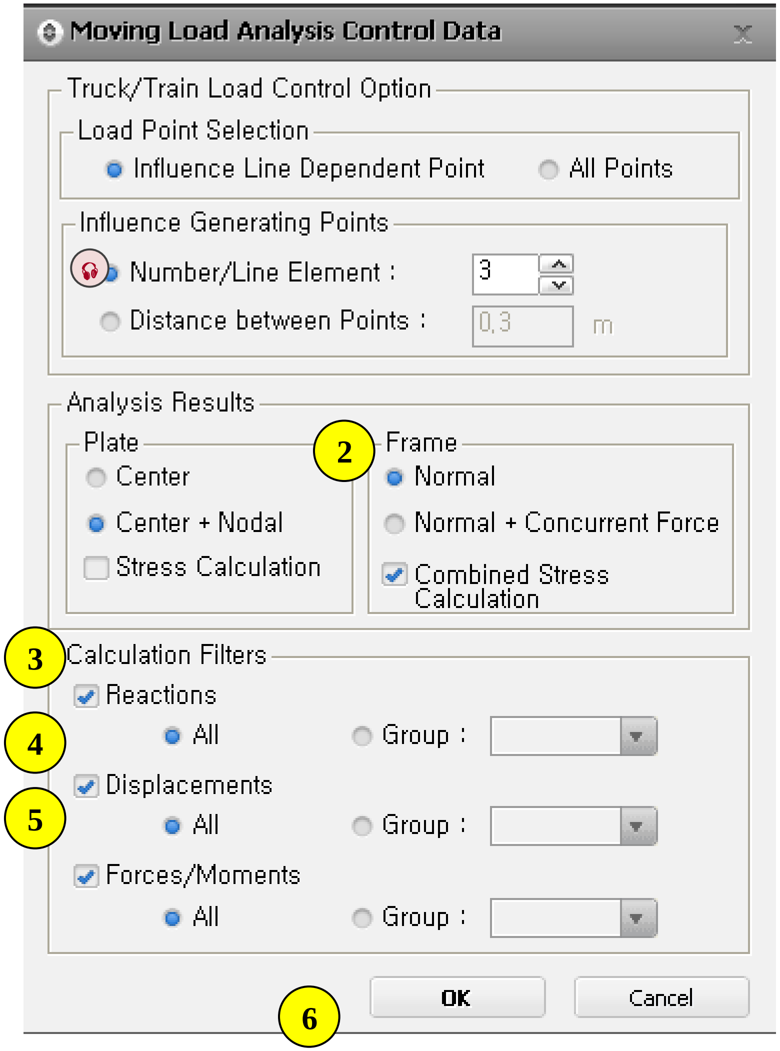
$$red\ \Phi_{2,3} = \Phi_{2,3} - \frac{h - 1,00}{10} \geq 1,0$$

Step 6-2. Railway Dynamic Factor by Element



- *As the determinant lengths have various values based on the type of structural element, the elements in one model may have different determinant lengths. In such case a dominant value of determinant lengths is specified for the global analysis, which we specified previously and then different determinant lengths can be specified using "Railway Dynamic Factor By Element". In this tutorial only global Dynamic Factor is applied.*
- *The Railway Dynamic Factor by Element function will amplify the element related results like forces and stresses but will not amplify the node specific results like deformations and reactions, which are amplified using global Railway Dynamic Factor.*

Step 7. Moving Load Analysis Option



1. ***Analysis > Moving Load Analysis Control…***
2. *Frame : **Normal***
3. *Reactions: **All***
4. *Displacements : **All***
5. *Forces/Moments: **All***
6. *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.

Step 8. Load Combination

	Load Case	Load Factor		
		ULS	SLS Characteristic	SLS Frequent
Permanent action	SW of Girders	1.35	1	1
	SW of CFs	1.35	1	1
	SW of Deck Slab	1.35	1	1
	SW of Haunch	1.35	1	1
	SW of Forms	1.35	1	1
	SDL Parapets	1.35	1	1
	SDL FWS	1.35	1	1
Railway action	MV ULS	1	0	0
	MV SLS C	0	1	0
	MV SLS F	0	0	1

MV ULS: Envelope of the load cases, LM71_ULS, SW/0_ULS, SW/2+LM71_ULS and SW/2+SW/0_ULS

MV SLS C: Envelope of the load cases, LM71_SLS C, SW/0_SLS C, SW/2+LM71_SLS C and SW/2+SW/0_SLS C

MV SLS F: Envelope of the load cases, LM71_SLS F, SW/0_SLS F, SW/2+LM71_SLS F and SW/2+SW/0_SLS F

Step 8. Load Combination (continued)

There are two ways to define load combinations; they are auto-generation and manual input. For this particular tutorial, we will manually input load combinations as shown below.

Results > Load Combination

Load Combination 1

Name (ULS), Active (ON), Type (ADD)

Fill out the Load Cases and Factors field as shown below

SW of Girders	1.35
SW of CFs	1.35
SW of Deck Slab	1.35
SW of Haunch	1.35
SW of Forms	1.35
SDL Parapets	1.35
SDL FWS	1.35

LM71_ULS	1
SW/0_ULS	1
SW/2+LM71_ULS	1
SW/2+SW/0_ULS	1

Step 8. Load Combination (continued)

Load Combination 2

Name (SLS C), Active (ON), Type (ADD)

SW of Girders	1
SW of CFs	1
SW of Deck Slab	1
SW of Haunch	1
SW of Forms	1
SDL Parapets	1
SDL FWS	1

LM71_SLS C	1
SW/0_SLS C	1
SW/2+LM71_SLS C	1
SW/2+SW/0_SLS C	1

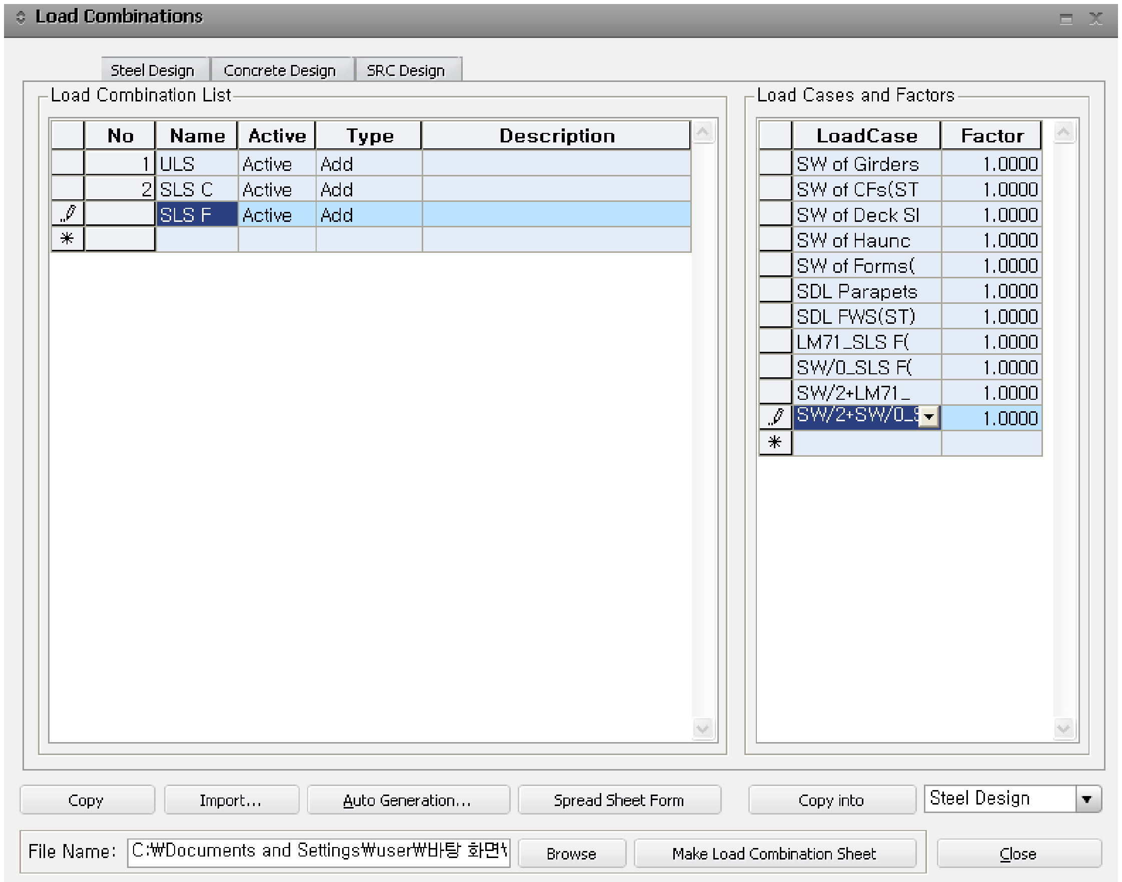
Load Combination 3

Name (SLS F), Active (ON), Type (ADD)

SW of Girders	1
SW of CFs	1
SW of Deck Slab	1
SW of Haunch	1
SW of Forms	1
SDL Parapets	1
SDL FWS	1

LM71_SLS F	1
SW/0_SLS F	1
SW/2+LM71_SLS F	1
SW/2+SW/0_SLS F	1

Step 8. Load Combination (continued)

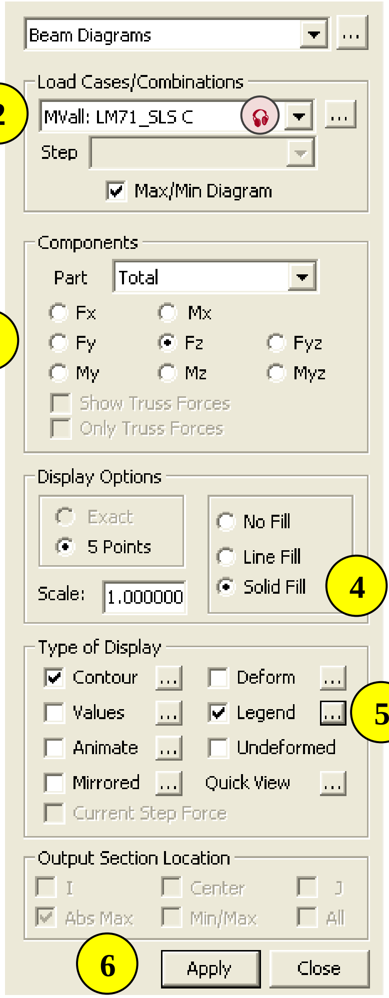


Step 9. Perform Analysis

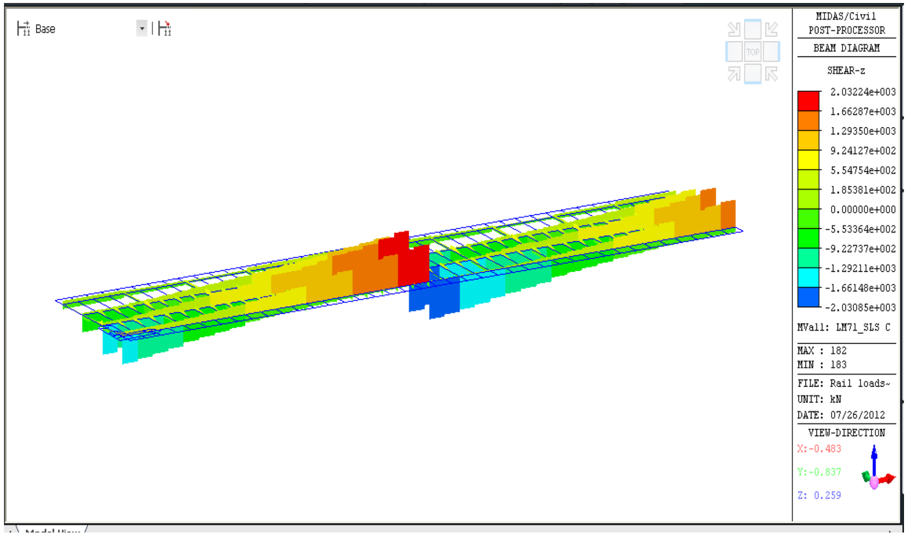
1. Click .

Step 10-1. Shear Force Diagrams

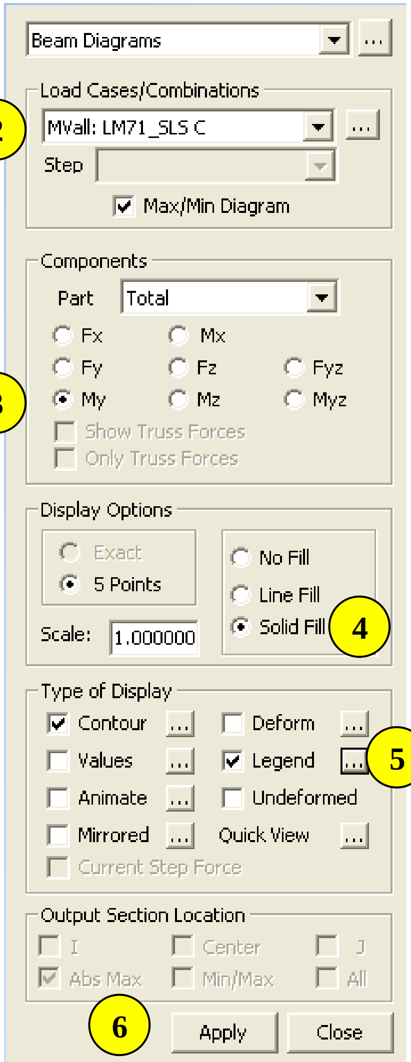
- *MVmin : The minimum force resulting from the vehicle load applied to the structure.*
- *MVmax: The maximum force resulting from the vehicle load applied to the structure.*
- *MVall: Both maximum and minimum force resulting from the vehicle load applied to the structure.*



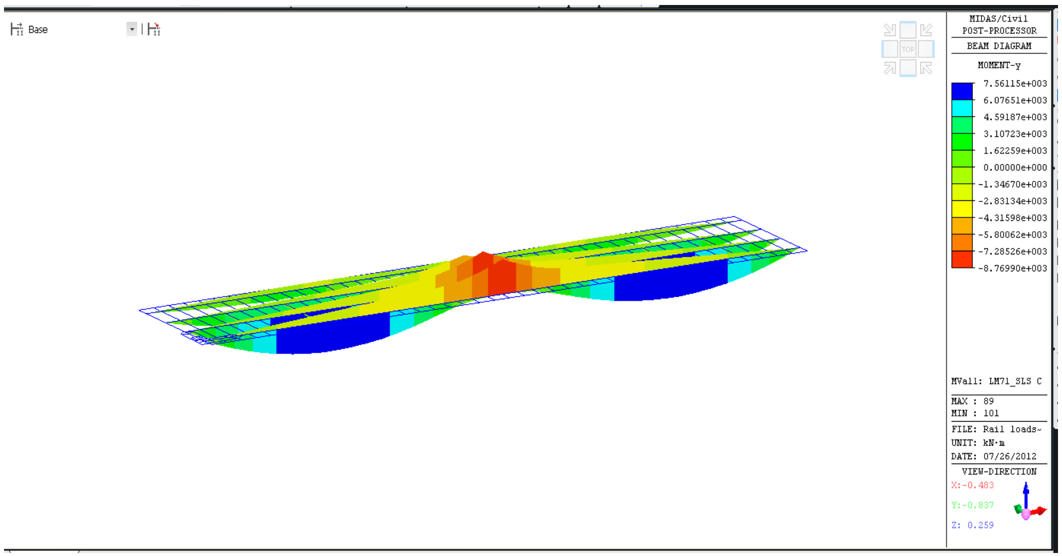
1. ***Results > Forces > Beam Diagrams…***
2. *Load Cases/Combinations :* ***Mvall: LM71_SLS C***
3. *Components :* ***Fz***
4. *Display Options :* ***Solid Fill***
5. *Check on* ***Legend****.*
6. *Click* **[Apply]** *button.*



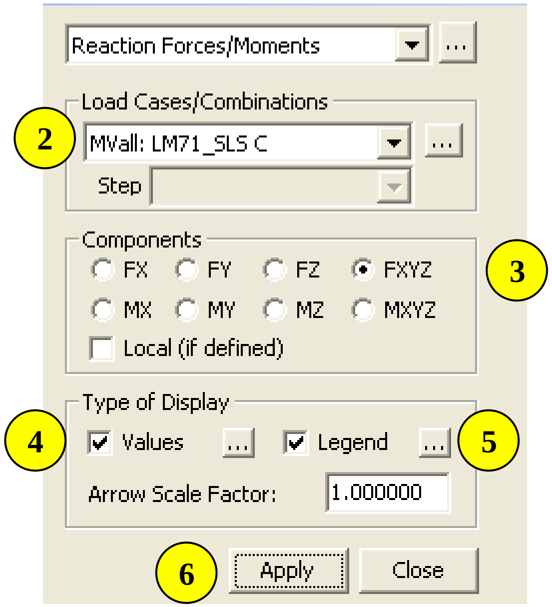
Step 10-2. Bending Moment Diagrams



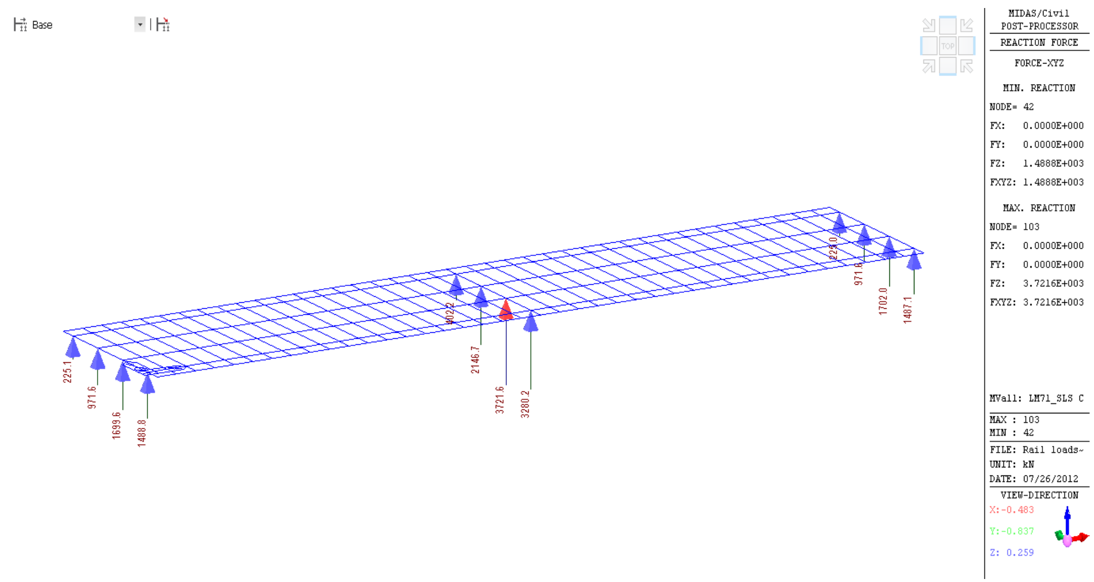
1. ***Results > Forces > Beam Diagrams…***
2. *Load Cases/Combinations : **MVall: LM71_SLS C***
3. *Components : **My***
4. *Display Options : **Solid Fill***
5. *Check on **Legend**.*
6. *Click* **[Apply]** *button.*



Step 10-3. Reactions



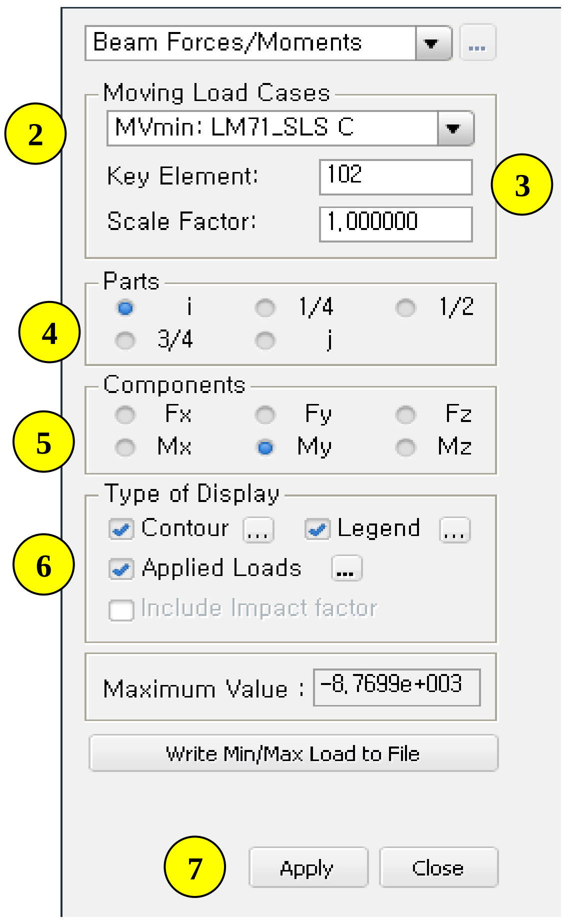
1. ***Results > Reactions > Reaction Forces /Moments…***
2. *Load Cases/Combinations :* ***Mvall: LM71_SLS C***
3. *Components :* ***FXYZ***
4. *Check on* ***Values****.*
5. *Check on* ***Legend****.*
6. *Click* **[Apply]** *button.*

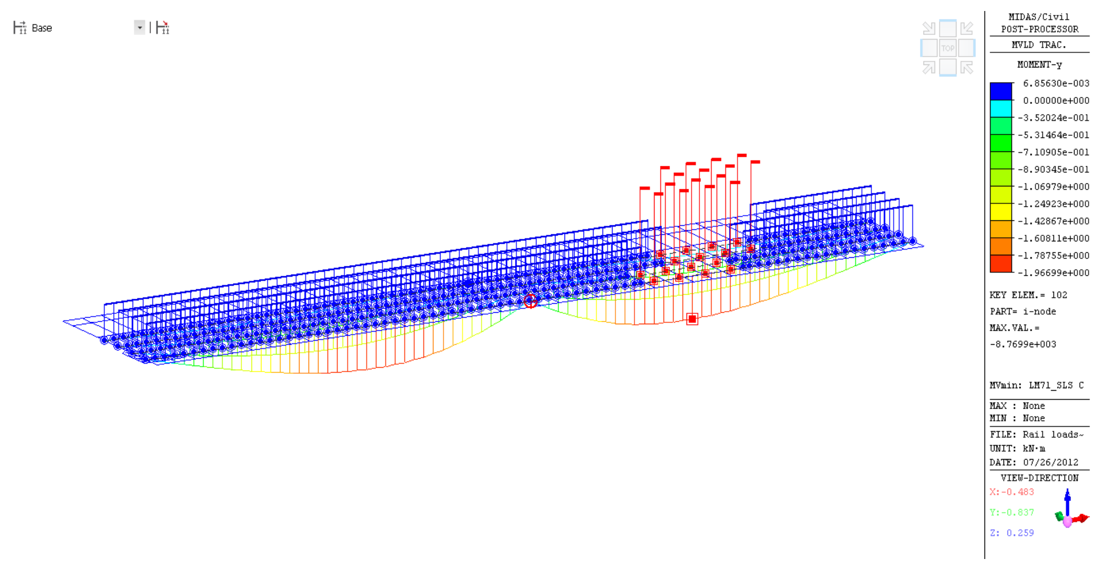


Step 10-4. Moving Load Tracer

The moving load tracer is used to display the vehicle position corresponding to the maximum negative moment at the i-end of element 102.

1. *Results > Moving Load Tracer > Beam Forces/Moments…*
2. *Moving Load Cases: **MVmin: LM71_SLS C***
3. *Key Element: **102***
4. *Parts: **i***
5. *Components: **My***
6. *Check on **Contour, Legend** and **Applied Loads.***
7. *Click **[Apply]** button.*





This is the end of this tutorial.

Reference: 1. EN 1991-2
2. EN 1990 Annex A2

Any questions or comments? esupport@midasuser.com