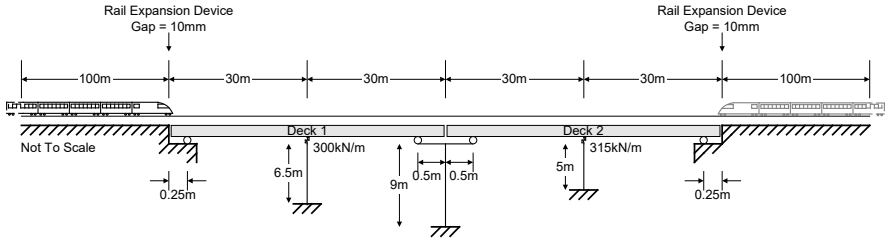
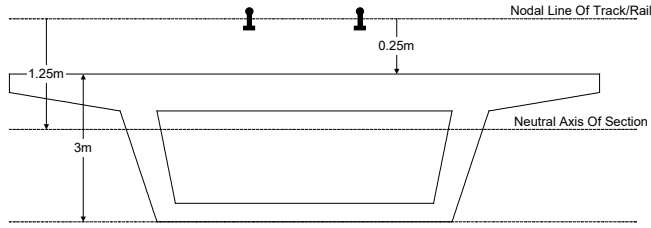
Rail Track-Structure Interaction with Offset Bearings and Train Loading Groups

For LUSAS version:	24.0
For software product(s):	LUSAS *Bridge*
With product option(s):	Nonlinear, Rail Track
Note: The example exceeds the limits of the LUSAS Teaching and Training Version.	

Description

This example examines the track-structure interaction between three braking train configurations and a double span bridge with bearings inboard of the ends of the decks. It considers the cases where the trainsets are just about to enter the left-side side of the structure through to the rear of the train exiting the right-hand side for each of the trainsets.





Objectives

The modelling requirements of the analysis are:

- Accurate modelling of the offset of the deck bearings from the ends of the decks.
- Modelling of expansion joints within the track at the start and end of the structure.
- Modelling of three train configurations (EuroCode SW/0, SW/2 and HSLM-A1).

The output requirements of the analysis for all train configurations passing across the structure are:

- Maximum relative displacement between the track and the structure in the longitudinal direction (relative railbed displacement).
- Peak longitudinal displacements between the deck ends / abutments.
- Peak longitudinal reactions at the abutments and piers.
- Peak axial rail stresses.

Keywords

UIC774-3, Track-Structure Interaction, TSI, Rail, Railbed, Offset Bearings, Train Loading Groups.

Associated Files

This file below is intended for copying to a project folder if a rail track model is to be defined from scratch. It is provided in the C:\Program Files\<LUSAS>Programs\scripts\User folder.

- **UIC_Template.xlsx** UIC774-3 XLSX input spreadsheet (unpopulated) for copying to a projects folder and using with this worked example.

The following files are intended for copying to a projects folder if results processing only and not spreadsheet data input is of interest. They are contained within a zip file that can be downloaded from the user area of the LUSAS website.

This file is intended for the definition of the HSLM-A1 loading:

- **HSLM-A1.xlsx** XLSX spreadsheet defining the loading layout for a HSLM-A1 train to be used with this worked example.

These files are intended for copying to a projects folder if results processing only and not spreadsheet data input is of interest:

- **RTA_2DeckBearingOffset_3TLG.xlsx** UIC774-3 XLSX input spreadsheet populated with data defined in this example. If used, continue at the section titled *Modelling / Running an Analysis*.
- **RTA_2DeckBearingOffset_3TLG-300mEmbankments.xlsx** UIC774-3 XLSX input spreadsheet populated with data defined in this example but with 300 m long approach embankments. This is for confirmation of the correct rail stresses away from the structure for the temperature loading.

Defining Model Data

The LUSAS Rail Track Analysis software option automatically builds LUSAS models suitable for track-structure interaction analysis. It does so from data defined in Microsoft Excel XLSX format spreadsheets.

If you wish to build the model used in the worked example from a predefined populated spreadsheet continue at the section titled ***Modelling / Running an Analysis***.

Otherwise, to see the processes involved in defining data to build a model from scratch:

- Copy the XLSX spreadsheet named **UIC_Template.xlsx** to a working projects folder where the track-structure interaction model is to be built.
- Rename the spreadsheet to **RTA_2DeckBearingOffset_3TLG.xlsx** .

- Open the spreadsheet in Microsoft Excel or an equivalent application that can edit the file.

The modelling spreadsheet contains six worksheets titled:

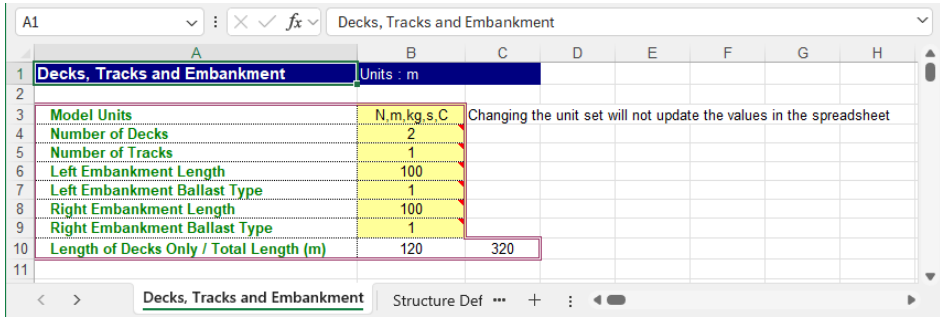
- ❑ **Decks, Tracks and Embankment**
- ❑ **Structure Definition**
- ❑ **Geometric Properties**
- ❑ **Material Properties**
- ❑ **Interaction and Expansion Joint**
- ❑ **Loading**

Note. Data should only be entered into the yellow regions of the XLSX spreadsheet to define the modelling and analysis requirements. Numeric values in the white cells are automatically populated according to data entered in other worksheets. These cells are protected from editing or user input. Data tips and other details relating to cells can often be seen by hovering over a cell.

Note. Whilst it is recommended that an unpopulated spreadsheet is used with this example, populated spreadsheets are supplied for those not wishing to enter all details as listed or for use if any errors are encountered with user-input into the general spreadsheet that cannot easily be fixed.

Defining Decks, Tracks and Embankment Lengths

- Pick the **Decks, Tracks and Embankment** worksheet.



- Ensure that **Model Units** are set to **N,m,kg,s,C**.
- Enter **2** for the **Number of Decks**.
- Enter **1** for the **Number of Tracks**.

- The UIC774-3 Code of Practice specifies the minimum embankment lengths for the modelling should be 100 m and this will be used in this example. Enter **100** for both the **Left Embankment Length** and **Right Embankment Length**.
- Only a single ballast type will be defined for both the track-embankment-interaction and the track-structure interaction in the model. Enter **1** for the ID number of the **Left Embankment Ballast Type** and the **Right Embankment Ballast Type**.

Note that the **Length of Decks Only** and **Total Length** cells are populated using data on this and another worksheet. These cells are protected on this worksheet.

Note. Model data is entered in "convenient" SI or US units. When the model is built from the data in the spreadsheet, all input is converted to consistent SI units of N,m,kg,s and C, or to consistent US units of kip,ft,kslug,s,F (if initially specified). The first row of each worksheet states the units in use. Note that, by design, changing the model units in use (on the 'Decks, Tracks and Embankments' worksheet) does not convert the values in the spreadsheet.

Defining the Structure

Referring back to the illustration at the start of the example the structure definition will now be entered into the spreadsheet.

- Pick the **Structure Definition** worksheet.
- The left-hand abutment is modelled as fully restrained. Enter **R** for the **Spring Support for each Abutment/Pier** for the left end of the deck.
- The bearing at the left-hand abutment for Deck 1 is free so enter **F** for the **Bearing Springs on Top of each Pier** for the left end of the deck.
- The bearing at the left-hand abutment is not located at the extreme end of the deck but instead is located 0.25 m inboard of the end of the deck. Enter **0.25** for the **Bearing Offset from End of Deck** for the left end of Deck 1.

Deck 1 is comprised of two spans of 30 m and has a pier located halfway along its total length. The pier is 6.5 m high with a fully fixed base and supports a sprung bearing for the deck. The definition of this pier will now be entered.

- Enter **R** for the **Spring Support for each Abutment/Pier** for the pier located at the end of Span 1 of Deck 1.
- Enter **6.5** for the **Pier Height** at the end of Span 1.
- Enter **2** for the **Pier Geometric Assignment**. This ID will match a geometric definition in the **Geometric Properties** worksheet covered next.

- Enter **2** for the **Pier Material Assignment**. This ID will match a material definition in the **Material Properties** worksheet covered later.
- The bearing on the top of the pier has a longitudinal stiffness of 300 MN/m. Enter **300** for the **Bearing Springs on Top of each Pier** because the units for the worksheet entry are kN/mm.
- Enter **30** for the **Span Length** of Span 1 of Deck 1.
- Enter **1** for the **Geometric Assignment** for the span of the deck. This ID will match a geometric definition in the **Geometric Properties** worksheet covered next.
- Enter **1** for the **Material Assignment** for the span of the deck. This ID will match a material definition in the **Material Properties** worksheet covered later.
- Enter **1** for the **Ballast Type**. This ID will match a ballast definition in the **Interaction and Expansion Joint** worksheet covered later.

The right-hand end of Deck 1 (and the left-hand end of Deck 2) are supported by a 9m high pier with a fully fixed base. The bearings for both decks are free and inboard of the ends of the decks. The structure definition for Deck 1 will be defined first.

- Enter **R** for the **Spring Support for each Abutment/Pier** for the pier located at the end of Span 2 of Deck 1 (the end of Deck 1 as there are no further spans).
- Enter **9** for the **Pier Height** at the end of Deck 1.
- Enter **2** for the **Pier Geometric Assignment**. This ID will match a geometric definition in the **Geometric Properties** worksheet covered next.
- Enter **2** for the **Pier Material Assignment**. This ID will match a material definition in the **Material Properties** worksheet covered later.
- The bearing for the right-hand end of Deck 1 is free so enter **F** for the **Bearing Springs on Top of each Pier** for the end of the deck.
- The bearing at the right-hand end of Deck 1 is not located at the extreme end of the deck but instead is located 0.5 m inboard of the end of the deck. Enter **0.5** for the **Bearing Offset from End of Deck** for the right-hand end of Deck 1.
- Enter **30** for the **Span Length** of Span 2 of Deck 1.
- Enter **1** for the **Geometric Assignment** for the span of the deck. This ID will match a geometric definition in the **Geometric Properties** worksheet covered next.
- Enter **1** for the **Material Assignment** for the span of the deck. This ID will match a material definition in the **Material Properties** worksheet covered later.

- Enter **1** for the **Ballast Type**. This ID will match a ballast definition in the **Interaction and Expansion Joint** worksheet covered later.

This completes the structure definition for the first deck of the structure. The same procedure is followed for the definition of the second deck of the structure. The structure definition for the supporting pier at start of the next deck must exactly match the definition for the previous deck and therefore the **Spring Support for each Abutment/Pier**, **Pier Height**, **Pier Geometric Assignment** and **Pier Material Assignment** must be identical for the left-hand end of Deck 2 and the last span of Deck 1.

- For the left-hand end of Deck 2, enter **R** for the **Spring Support for each Abutment/Pier**, enter **9** for the **Pier Height**, enter **2** for the **Pier Geometric Assignment** and enter **2** for the **Pier Material Assignment** to match the data entered for the right-hand end of Deck 1.

- The bearing for the left-hand end of Deck 2 is free so enter **F** for the **Bearing Springs on Top of each Pier** for the end of the deck.

- The bearing at the left-hand end of Deck 2 is not located at the extreme end of the deck but instead is located 0.5 m inboard of the end of the deck. Enter **0.5** for the **Bearing Offset from End of Deck** for the left-hand end of Deck 2.

Deck 2 is also comprised of two spans of 30 m and has a pier located halfway along its total length. The pier is 5 m high with a fully fixed base and supports a sprung bearing for the deck. The definition of this pier will now be entered.

- Enter **R** for the **Spring Support for each Abutment/Pier** for the pier located at the end of Span 1 of Deck 2.

- Enter **5** for the **Pier Height** at the end of Span 1.

- Enter **2** for the **Pier Geometric Assignment**. This ID will match a geometric definition in the **Geometric Properties** worksheet covered next.

- Enter **2** for the **Pier Material Assignment**. This ID will match a material definition in the **Material Properties** worksheet covered later.

- The bearing on the top of the pier has a longitudinal stiffness of 315 MN/m. Enter **315** for the **Bearing Springs on Top of each Pier** because the units for the worksheet entry are kN/mm.

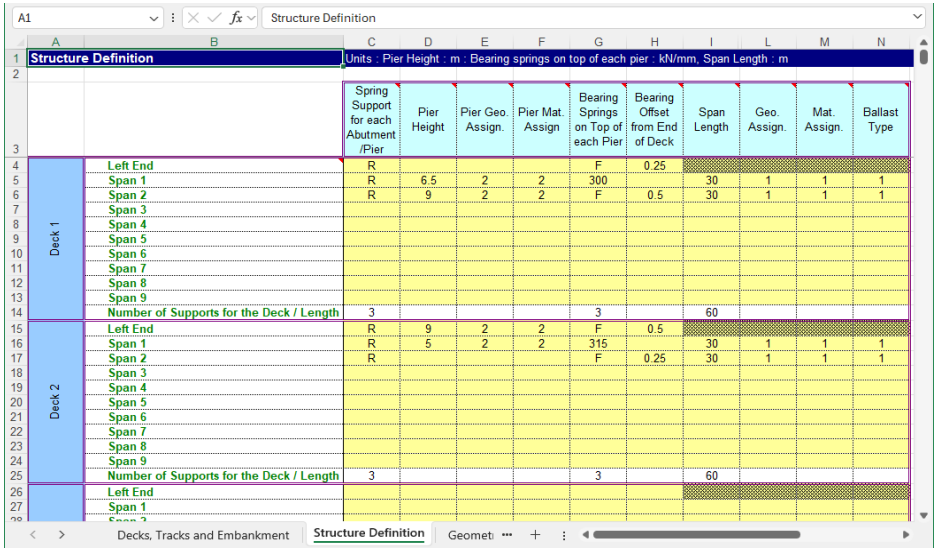
- Enter **30** for the **Span Length** of Span 1 of Deck 2.

- Enter **1** for the **Geometric Assignment** for the span of the deck. This ID will match a geometric definition in the **Geometric Properties** worksheet covered next.

- Enter **1** for the **Material Assignment** for the span of the deck. This ID will match a material definition in the **Material Properties** worksheet covered later.

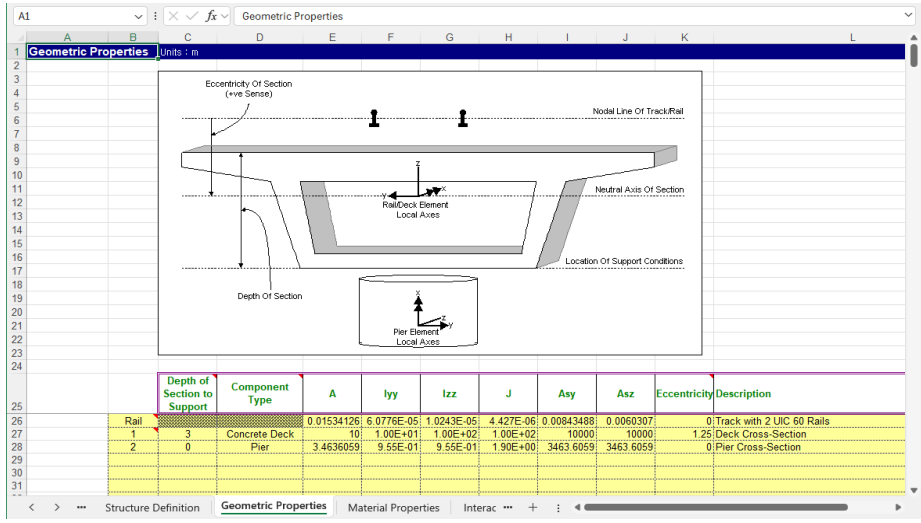
- Enter **1** for the **Ballast Type**. This ID will match a ballast definition in the **Interaction and Expansion Joint** worksheet covered later.
- The right-hand abutment is modelled as fully restrained. Enter **R** for the **Spring Support for each Abutment/Pier** for the end of Span 2 of Deck 2.
- The bearing at the right-hand abutment for Deck 2 is free so enter **F** for the **Bearing Springs on Top of each Pier** for the right-hand end of Span 2 of Deck 2.
- The bearing at the right-hand abutment is not located at the extreme end of the deck but instead is located 0.25 m inboard of the end of the deck. Enter **0.25** for the **Bearing Offset from End of Deck** for the right-hand end of Span 2 of Deck 2.
- Enter **30** for the **Span Length** of Span 2 of Deck 2.
- Enter **1** for the **Geometric Assignment** for the span of the deck. This ID will match a geometric definition in the **Geometric Properties** worksheet covered next.
- Enter **1** for the **Material Assignment** for the span of the deck. This ID will match a material definition in the **Material Properties** worksheet covered later.
- Enter **1** for the **Ballast Type**. This ID will match a ballast definition in the **Interaction and Expansion Joint** worksheet covered later.

The worksheet should look like this:



		Structure Definition	Units : Pier Height : m : Bearing springs on top of each pier : kN/mm, Span Length : m								
			Spring Support for each Abutment /Pier	Pier Height	Pier Geo. Assign.	Pier Mat. Assign	Bearing Springs on Top of each Pier	Bearing Offset from End of Deck	Span Length	Geo. Assign.	Mat. Assign.	Ballast Type
Deck 1		Left End	R				F	0.25				
		Span 1	R	6.5	2	2	300		30	1	1	1
		Span 2	R	9	2	2	F	0.5	30	1	1	1
		Span 3										
		Span 4										
		Span 5										
		Span 6										
		Span 7										
		Span 8										
		Span 9										
		Number of Supports for the Deck / Length	3				3		60			
Deck 2		Left End	R	9	2	2	F	0.5				
		Span 1	R	5	2	2	315		30	1	1	1
		Span 2	R				F	0.25	30	1	1	1
		Span 3										
		Span 4										
		Span 5										
		Span 6										
		Span 7										
		Span 8										
		Span 9										
		Number of Supports for the Deck / Length	3				3		60			
		Left End										
		Span 1										

Defining the Geometric Properties for the Structure



	Depth of Section to Support	Component Type	A	Iyy	Izz	J	Asy	Asz	Eccentricity	Description
Rail			0.01534126	6.0776E-05	1.0243E-05	4.427E-06	0.00843488	0.0060307	0	Track with 2 UIC 60 Rails
1	3	Concrete Deck	10	1.00E+01	1.00E+02	1.00E+02	10000	10000	1.25	Deck Cross-Section
2	0	Pier	3.4636059	9.55E-01	9.55E-01	1.90E+00	3463.6059	3463.6059	0	Pier Cross-Section

- Pick the **Geometric Properties** worksheet.

The first line of data should always be called **Rail** and contains the geometric properties for the rail track. All other lines define the geometric properties for the unique IDs used in the **Structure Definition** worksheet.

The track is formed of two UIC 60 rails and for the purposes of this example the properties are obtained by doubling the values from the LUSAS section library to give the total value per track. Enter the following values for the rail track:

- Enter **0.01534126** for the area (**A**) in m^2 of the two rails of the track.
- Enter **6.07756E-5** for the second moment of inertia about the horizontal y-axis (**Iyy**) in m^4.
- Enter **1.024324E-5** for the second moment of inertia about the vertical z-axis (**Izz**) in m^4.
- Enter **4.42698E-6** for the torsional constant (**J**) in m^4.
- Enter **8.43488E-3** for the shear area for the y-direction (**Asy**) in m^2.
- Enter **6.0307E-3** for the shear area for the z-direction (**Asz**) in m^2.
- Enter **0** for the **Eccentricity** in the rail in m.
- Enter **Track with 2 UIC 60 Rails** in the **Description** for the rails.

Note. The UIC774-3 Code of Practice assumes that a 2D analysis is performed where the longitudinal and vertical behaviours of the track and structure are of interest. The current rail track analysis also assumes a 2D analysis but for its solution it requires the features of an element type which is only available in 3D in LUSAS. The properties entered into the worksheet therefore require geometric properties for all freedoms of the 3D element and the lateral behaviour and torsion the properties for two rails have been assumed to be twice those of the single rail. This has been discussed further in the ***Modelling Discussion*** section of the example that replicates the UIC774-3 E1-3 and E4-6 fundamental tests.

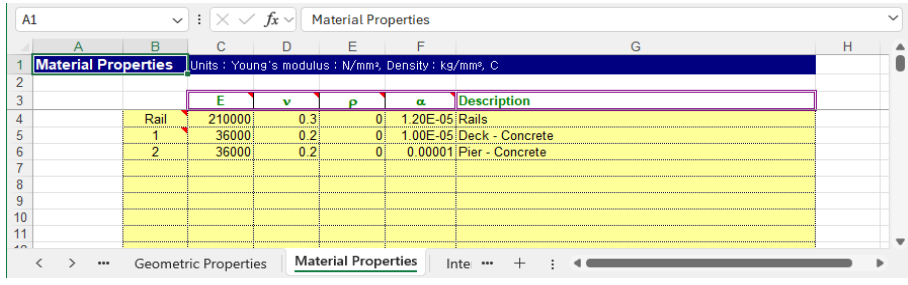
The deck geometric properties are now defined in the **Geometric** Properties worksheet. As for the track rails, while the analysis is 2D the elements used are 3D so dummy properties have been included for the lateral behaviour and torsion of the deck although these will not affect the results obtained. In the model it has therefore been assumed that these properties are equal to the values provided for the vertical behaviour. Enter the following values for the deck:

- Enter **1** for the ID in the first column to match the geometric assignment ID for the deck in the **Structure Definition** worksheet.
- Enter **3** for the **Depth of Section** in m.
- Select **Concrete Deck** from the Component Type list. The deck constructed from concrete and this type will be used later in the Loading worksheet to apply the temperature loadings to the model.
- Enter **10** for the area (**A**) in m^2.
- Enter **10** for the second moment of inertia about the horizontal y-axis (**Iyy**) in m^4.
- Enter **100** for the second moment of inertia about the vertical z-axis (**Izz**) in m^4.
- Enter **100** for the torsional constant (**J**) in m^4.
- Enter **10000** for the shear area for the y-direction (**Asy**) in m^2. The shear deformations have been ignored by setting the shear area to 1000*A in accordance with the *Element Reference Manual*.
- Enter **10000** for the shear area for the z-direction (**Asz**) in m^2.
- Enter **1.25** for the **Eccentricity** in the deck in m. The track is 0.25 m above the top surface of the section. and the neutral axis is 1.0 m from the top of the section. The eccentricity of the deck section neutral axis from the track is therefore 1.25 m.
- Enter **Deck Cross-Section** in the **Description** for the deck.

The pier geometric properties are now defined in the **Geometric** Properties worksheet. The pier is circular with a diameter of 2.1 m. Enter the following values for the deck:

- Enter **2** for the ID in the first column to match the geometric assignment ID for the piers in the **Structure Definition** worksheet.
- Enter **0** for the **Depth of Section** in m. The depth of section is not used for pier assignments, only for deck assignments.
- Select **Pier** from the Component Type list. Pier geometric components are not assigned temperature loadings from the Loading worksheet.
- Enter **3.4636059** for the area (**A**) in m^2.
- Enter **0.9546564** for the second moment of inertia about the horizontal y-axis (**Iyy**) in m^4.
- Enter **0.9546564** for the second moment of inertia about the vertical z-axis (**Izz**) in m^4.
- Enter **1.9006014** for the torsional constant (**J**) in m^4.
- Enter **3463.6059** for the shear area for the y-direction (**Asy**) in m^2 to exclude shear deformations in accordance with the *Element Reference Manual*.
- Enter **3463.6059** for the shear area for the z-direction (**Asz**) in m^2 to exclude shear deformations in accordance with the *Element Reference Manual*.
- Enter **0** for the **Eccentricity** in the pier in m.
- Enter **Pier Cross-Section** in the **Description** for the pier.

Defining the Material Properties for the Structure



Material Properties	Units : Young's modulus : N/mm², Density : kg/mm³, C				
	E	ν	ρ	α	Description
Rail	210000	0.3	0	1.20E-05	Rails
1	36000	0.2	0	1.00E-05	Deck - Concrete
2	36000	0.2	0	0.00001	Pier - Concrete

- Pick the **Material Properties** worksheet.

The first line of data should always be called **Rail** and contains the material properties for the rail track. All other lines define the material properties for the unique IDs used in the **Structure Definition** worksheet.

Enter the following values for the rail:

- Enter **210000** for the Young's modulus (**E**) in N/mm^2 which is equivalent to a value of 210 GPa.
- Enter **0.3** for the Poisson's ratio (ν).
- Enter **0** for the mass density (ρ). Setting this to the representative value allows the self-weight deflections to be calculated for the structure and track system if they are required but it is not used for the track-structure interaction analysis.
- Enter **1.20E-5** for the coefficient of thermal expansion (α).
- Enter **Rails** in the **Description** for the rails.

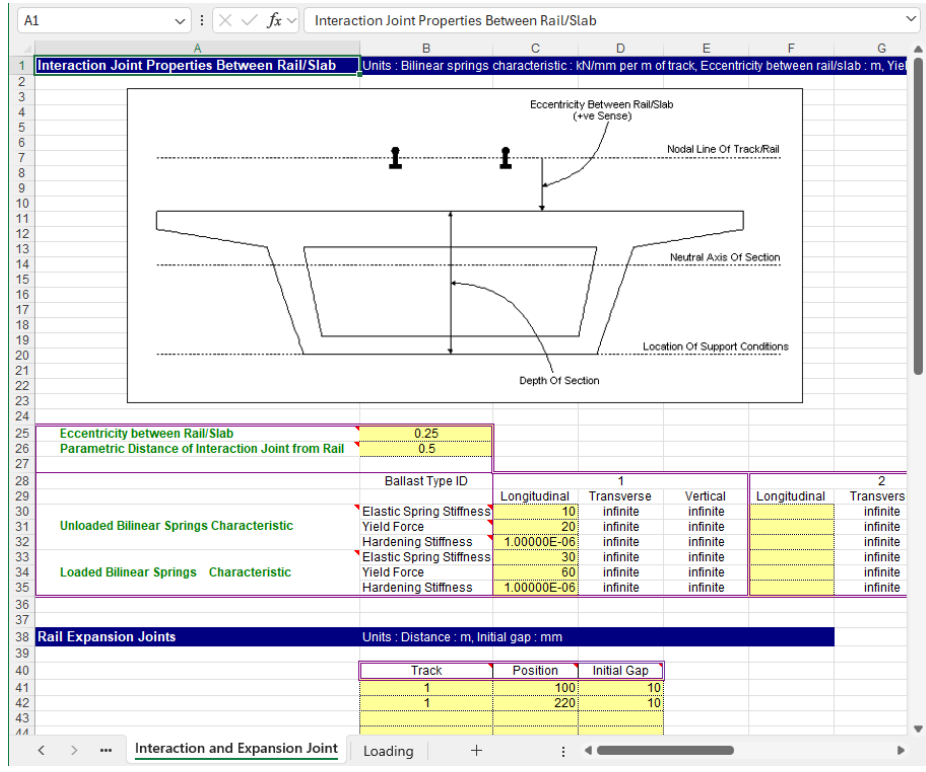
Enter the following values for the deck:

- Enter **1** for the ID in the first column to match the material assignment ID for the deck in the **Structure Definition** worksheet.
- Enter **36000** for the Young's modulus (**E**) in N/mm^2.
- Enter **0.2** for the Poisson's ratio (ν).
- Enter **0** for the mass density (ρ).
- Enter **1.0E-5** for the coefficient of thermal expansion (α).
- Enter **Deck - Concrete** in the **Description** for the material properties.

Enter the following values for the pier:

- Enter **2** for the ID in the first column to match the material assignment ID for the deck in the **Structure Definition** worksheet.
- Enter **36000** for the Young's modulus (**E**) in N/mm^2.
- Enter **0.2** for the Poisson's ratio (ν).
- Enter **0** for the mass density (ρ).
- Enter **1.0E-5** for the coefficient of thermal expansion (α).
- Enter **Pier - Concrete** in the **Description** for the material properties.

Defining the Track-Structure Interaction and Expansion Joint Properties for the Structure



- Pick the **Interaction and Expansion Joint** worksheet.
- Enter **0.25** for the eccentricity between the rail and slab as the track is 0.25 m above the top of the deck.
- Enter **0.5** for the Parametric Distance of Interaction Joint from Rail. For the modelling of the eccentricity between the rail and the slab this will place the interaction joints halfway between the track and slab.

Enter the following values for the longitudinal bilinear spring characteristics for **Ballast Type ID 1** – (Only ballast type ID 1 has been assigned in the **Decks, Tracks and Embankment** and the **Structure Definition** worksheets):

- Enter **10** for the **Unloaded Elastic Spring Stiffness** in the longitudinal direction in kN/m/mm. The u_0 in the bilinear interaction behaviour is equal to 2 mm which is the representative value for the resistance of a sleeper in ballast. The resistance k in the plastic zone for the track is taken as k = 20 kN/m which represents the unloaded

resistance of sleepers in ballast with good maintenance (from UIC774-3). This gives a stiffness of 20 kN/m / 2 mm = 10 kN/m/mm.

- Enter **20** for the **Unloaded Yield Force** in the longitudinal direction in kN/m. This parameter is equivalent to the resistance in the plastic zone, k.
- Enter **1.0E-6** for the **Unloaded Hardening Stiffness** in the longitudinal direction in kN/m/mm. Zero cannot be entered but a very small hardening stiffness will maintain the force in the interaction joints at the unloaded yield force.
- Enter **30** for the **Loaded Elastic Spring Stiffness** in the longitudinal direction in kN/m/mm. The u_0 in the bilinear interaction behaviour is again equal to 2 mm which is the representative value for the resistance of a sleeper in ballast. The resistance k in the plastic zone for the track is taken as k = 60 kN/m which represents the resistance of loaded track (from UIC774-3). This gives a stiffness of 60 kN/m / 2 mm = 30 kN/m/mm.
- Enter **60** for the **Loaded Yield Force** in the longitudinal direction in kN/m.
- Enter **1.0E-6** for the **Loaded Hardening Stiffness** in the longitudinal direction in kN/m/mm. Again, zero cannot be entered but a very small hardening stiffness will maintain the force in the interaction joints at the loaded yield force.

Note. The interaction springs are modelled using nonlinear joints with elastic-perfectly plastic behaviour in the longitudinal direction. This is achieved using the elasto-plastic uniform tension and compression material where the hardening stiffness should always be set to a very small value to avoid numerical instabilities.

The track includes expansion devices (joints) at each of the abutments, each with an initial gap of 10 mm. The details of these are also defined in the **Interaction and Expansion Joint** worksheet.

Enter the following values for the rail expansion joints:

- Enter **1** for the track ID in the first column for the expansion joint in the single track at the left-hand abutment.
- Enter **100** for the **Position** of the expansion joint in Track 1 at the left-hand abutment. All expansion joint positions are defined from the left-hand extent of the model including the embankment. The left-hand approach embankment is 100 m in length and therefore the position at the left-hand abutment is equal to 100 m.
- Enter **10** for the **Initial Gap** of the expansion joint in Track 1 at the left-hand abutment. This means that it takes 10 mm of relative movement of the track ends in the longitudinal direction either side of the expansion joint to close the gap.
- Enter **1** for the track ID in the first column for the expansion joint in the single track at the right-hand abutment.

- Enter **220** for the **Position** of the expansion joint in Track 1 at the right-hand abutment. All expansion joint positions are defined from the left-hand extent of the model including the embankment. The left-hand approach embankment is 100 m in length and the structure is 120 m in length, therefore the position is equal to 220 m.
- Enter **10** for the **Initial Gap** of the expansion joint in Track 1 at the right-hand abutment. This means that it takes 10 mm of relative movement of the track ends in the longitudinal direction either side of the expansion joint to close the gap.

Defining the Temperature and Trainset Loading for the Structure

The analysis includes the effects of three different trainset configurations passing over the structure. Each of these trainset configurations will be defined in a separate Train Loading Group within the **Loading** worksheet. The temperature loading to the tracks and decks is also defined within the **Loading** worksheet.

- Pick the **Loading** worksheet.

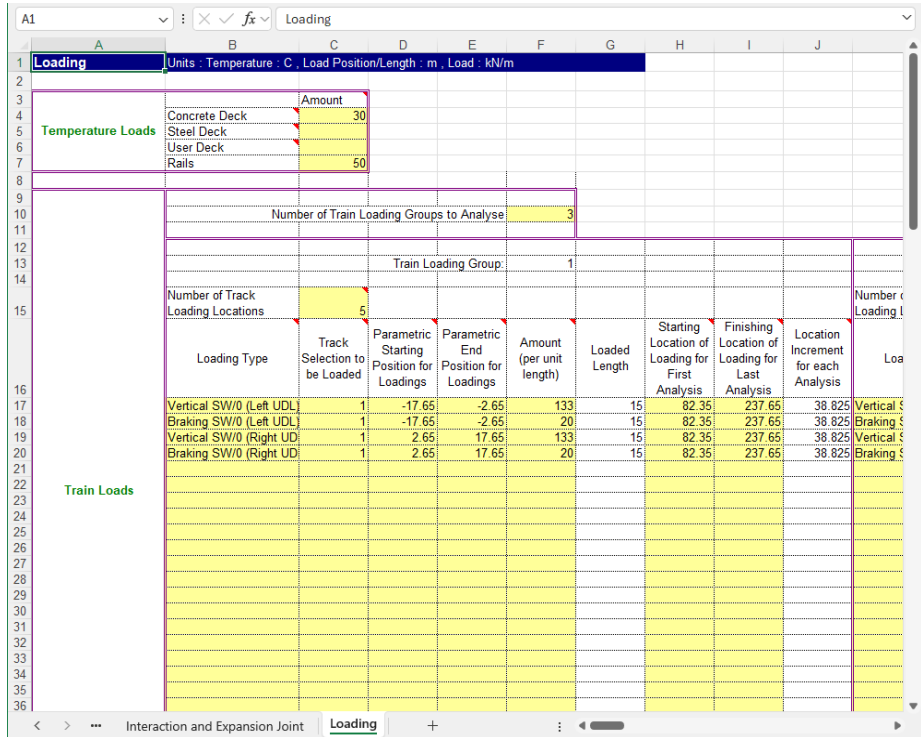
The temperature loading will be defined first. Enter the following values for the temperature loading:

- Enter **30** for the **Temperature** variation of the **Concrete Deck** in °C.
- Enter **50** for the **Temperature** variation of the **Rails** in °C.

The number of Train Loading Groups to be analysed should be specified. Sometimes this number may not be known until all of the trainsets (combinations of trainsets if there is loading to more than one track) have all been input for a structure but for this example we know that there are three independent trainsets being passed along the single track. There is one in each Train Loading Group, so they are analysed with only one trainset configuration on the structure at any one time but with all trainsets / positions considered from the analysis when we eventually post-process the results of the analysis.

- Enter **3** for the **Number of Train Loading Groups to Analyse** in the train loads section of the worksheet.

Note. If more Train Loading Groups are defined in the worksheet than is specified in the **Number of Train Loading Groups to Analyse** entry of the worksheet the additional definitions above the number will be excluded from the analysis.



1	Loading	Units : Temperature : C , Load Position/Length : m , Load : kN/m								
3	Temperature Loads		Amount							
4		Concrete Deck	30							
5		Steel Deck								
6		User Deck								
7		Rails	50							
10	Train Loads	Number of Train Loading Groups to Analyse				3				
13				Train Loading Group:		1				
15		Number of Track Loading Locations	5							Number o Loading L
16		Loading Type	Track Selection to be Loaded	Parametric Starting Position for Loadings	Parametric End Position for Loadings	Amount (per unit length)	Loaded Length	Starting Location of Loading for First Analysis	Finishing Location of Loading for Last Analysis	Location Increment for each Analysis	Loa
17		Vertical SW/0 (Left UDL)	1	-17.65	-2.65	133	15	82.35	237.65	38.825	Vertical S
18		Braking SW/0 (Left UDL)	1	-17.65	-2.65	20	15	82.35	237.65	38.825	Braking S
19		Vertical SW/0 (Right UD	1	2.65	17.65	133	15	82.35	237.65	38.825	Vertical S
20		Braking SW/0 (Right UD	1	2.65	17.65	20	15	82.35	237.65	38.825	Braking S

For the analysis all three of the trainsets travel from arrival at the left-hand abutment of the structure through to departure at the right-hand abutment of the structure. The configurations / lengths of the trainset loadings for each of the Train Loading Groups is different and therefore separate movement definitions will be required for each of these. The trainset definitions will be entered in the following order: SW/0, SW/2 and HSLM-A1.

SW/0 trainset loading

The SW/0 loading consists of UDLs representing the vertical and braking loads. These will be defined in the worksheet with meaningful names with the origin of the load defined at the centre.

Enter the following values for Train Loading Group 1, the SW/0 loading:

- Enter **5** for the **Number of Track Loading Locations** for the passage of the SW/0 trainset from the left-hand abutment to the right-hand abutment. This is a low value for example purposes, and a true analysis would require more locations to fully describe the passage of the trainset loading across the structure.

- Enter **Vertical SW/0 (Left UDL)** for the **Loading Type** in the first row of loading. The type of loading is defined by the first character of the description, thus allowing more detailed descriptions for more complex loading configurations.
- Enter **1** in the **Track Selection to be Loaded** since there is only a single track in the analysis.
- Enter **-17.65** for the **Parametric Starting Position for Loadings** (in m) to indicate the left-hand limit of the left UDL vertical loading.
- Enter **-2.65** for the **Parametric End Position for Loadings** (in m) to indicate the right-hand limit of the left UDL vertical loading.
- Enter **133** for the **Amount (per unit length)** to apply 133 kN/m vertically downwards for the left UDL vertical loading.
- Enter **82.35** for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis (locations are defined from the left-hand extent of the model including the embankment). The SW/0 loading is symmetrical about the origin meaning that, with a 100 m left-hand embankment, the starting location for the origin of the loading is equal to (100 - 17.65) = 82.35 m.
- Enter **237.65** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis (locations are defined from the left-hand extent of the model including the embankment). The SW/0 loading is symmetrical about the origin meaning that, with a 100 m left-hand embankment and 120 m structure, the finishing location for the origin of the loading is equal to (100 + 120 + 17.65) = 237.65 m.

This completes the definition for the left UDL representing the vertical loading of the SW/0 trainset. The braking load for the left-hand loading and vertical plus braking loading for the right-hand part of the SW/0 trainset still needs to be defined.

Enter the following values for Train Loading Group 1, the SW/0 loading:

- Enter **Braking SW/0 (Left UDL)** for the **Loading Type** in the next row of loading.
- Enter **1** in the **Track Selection to be Loaded** since there is only a single track in the analysis.
- Enter **-17.65** again for the **Parametric Starting Position for Loadings** (in m) to indicate the left-hand limit of the left UDL braking loading (which should be placed over the same extents as the vertical loading).
- Enter **-2.65** again for the **Parametric End Position for Loadings** (in m) to indicate the right-hand limit of the left UDL braking loading (which should be placed over the same extents as the vertical loading).

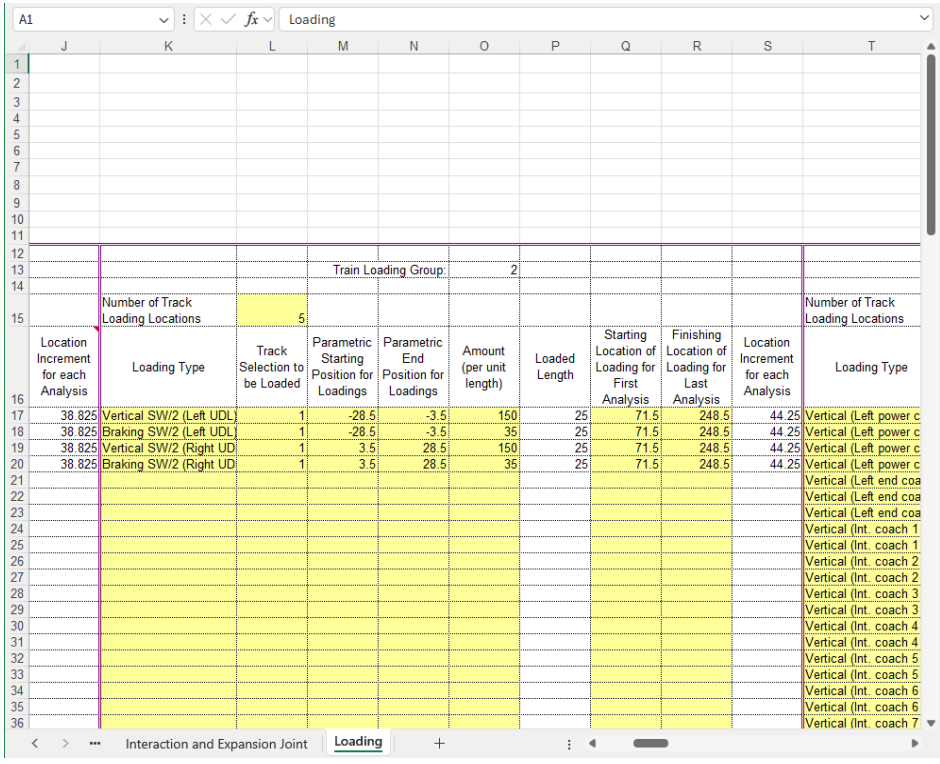
- Enter **20** for the **Amount (per unit length)** to apply 20 kN/m horizontal braking forces acting to the right for the SW/0 trainset moving from left to right.
- Enter **82.35** again for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis.
- Enter **237.65** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis.
- Enter **Vertical SW/0 (Right UDL)** for the **Loading Type** in the next row of loading.
- Enter **1** in the **Track Selection to be Loaded** since there is only a single track in the analysis.
- Enter **2.65** for the **Parametric Starting Position for Loadings** (in m) to indicate the left-hand limit of the right UDL vertical loading.
- Enter **17.65** for the **Parametric End Position for Loadings** (in m) to indicate the right-hand limit of the right UDL vertical loading.
- Enter **133** for the **Amount (per unit length)** to apply 133 kN/m vertically downwards for the right UDL vertical loading.
- Enter **82.35** again for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis.
- Enter **237.65** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis.
- Enter **Braking SW/0 (Right UDL)** for the **Loading Type** in the next row of loading.
- Enter **1** in the **Track Selection to be Loaded** since there is only a single track in the analysis.
- Enter **2.65** for the **Parametric Starting Position for Loadings** (in m) to indicate the left-hand limit of the right UDL braking loading.
- Enter **17.65** for the **Parametric End Position for Loadings** (in m) to indicate the right-hand limit of the right UDL braking loading.
- Enter **20** for the **Amount (per unit length)** to apply 20 kN/m horizontal braking forces acting to the right for the SW/0 trainset moving from left to right.

- Enter **82.35** again for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis.
- Enter **237.65** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis.

This completes the definition for the SW/0 trainset loading in Train Loading Group 1. The trainset loading definitions of the remaining two Train Loading Groups still needs to be defined and is detailed below.

SW/2 trainset loading

The SW/2 trainset loading has a very similar layout (albeit with different dimensions) to the SW/0 trainset loading defined above and therefore the input for the SW/2 trainset is detailed below without further explanation.



			Train Loading Group		2					
	Number of Track Loading Locations	5								Number of Track Loading Locations
Location Increment for each Analysis	Loading Type	Track Selection to be Loaded	Parametric Starting Position for Loadings	Parametric End Position for Loadings	Amount (per unit length)	Loaded Length	Starting Location of Loading for First Analysis	Finishing Location of Loading for Last Analysis	Location Increment for each Analysis	Loading Type
38.825	Vertical SW/2 (Left UDL)	1	-28.5	-3.5	150	25	71.5	248.5	44.25	Vertical (Left power c
38.825	Braking SW/2 (Left UDL)	1	-28.5	-3.5	35	25	71.5	248.5	44.25	Vertical (Left power c
38.825	Vertical SW/2 (Right UD	1	3.5	28.5	150	25	71.5	248.5	44.25	Vertical (Left power c
38.825	Braking SW/2 (Right UD	1	3.5	28.5	35	25	71.5	248.5	44.25	Vertical (Left power c
										Vertical (Left end coa
										Vertical (Left end coa
										Vertical (Left end coa
										Vertical (Int. coach 1
										Vertical (Int. coach 1
										Vertical (Int. coach 2
										Vertical (Int. coach 2
										Vertical (Int. coach 3
										Vertical (Int. coach 3
										Vertical (Int. coach 4
										Vertical (Int. coach 4
										Vertical (Int. coach 5
										Vertical (Int. coach 5
										Vertical (Int. coach 6
										Vertical (Int. coach 6
										Vertical (Int. coach 7

Enter the following values for Train Loading Group 2, the SW/2 loading:

- Enter **5** for the **Number of Track Loading Locations** for the passage of the SW/2 trainset from the left-hand abutment to the right-hand abutment. This is a low value

for example purposes and a true analysis would require more locations to fully describe the passage of the trainset loading across the structure.

- Enter **Vertical SW/2 (Left UDL)** for the **Loading Type** in the first row of loading.
- Enter **1** in the **Track Selection to be Loaded** since there is only a single track in the analysis.
- Enter **-28.5** for the **Parametric Starting Position for Loadings** (in m) to indicate the left-hand limit of the left UDL vertical loading.
- Enter **-3.5** for the **Parametric End Position for Loadings** (in m) to indicate the right-hand limit of the left UDL vertical loading.
- Enter **150** for the **Amount (per unit length)** to apply 150 kN/m vertically downwards for the left UDL vertical loading.
- Enter **71.5** for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis (locations are defined from the left-hand extent of the model including the embankment).
- Enter **248.5** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis (locations are defined from the left-hand extent of the model including the embankment).
- Enter **Braking SW/2 (Left UDL)** for the **Loading Type** in the next row of loading.
- Enter **1** in the **Track Selection to be Loaded** since there is only a single track in the analysis.
- Enter **-28.5** again for the **Parametric Starting Position for Loadings** (in m) to indicate the left-hand limit of the left UDL braking loading (which should be placed over the same extents as the vertical loading).
- Enter **-3.5** again for the **Parametric End Position for Loadings** (in m) to indicate the right-hand limit of the left UDL braking loading (which should be placed over the same extents as the vertical loading).
- Enter **35** for the **Amount (per unit length)** to apply 35 kN/m horizontal braking forces acting to the right for the SW/2 trainset moving from left to right.
- Enter **71.5** again for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis.

- Enter **248.5** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis.
- Enter **Vertical SW/2 (Right UDL)** for the **Loading Type** in the next row of loading.
- Enter **1** in the **Track Selection to be Loaded** since there is only a single track in the analysis.
- Enter **3.5** for the **Parametric Starting Position for Loadings** (in m) to indicate the left-hand limit of the right UDL vertical loading.
- Enter **28.5** for the **Parametric End Position for Loadings** (in m) to indicate the right-hand limit of the right UDL vertical loading.
- Enter **150** for the **Amount (per unit length)** to apply 150 kN/m vertically downwards for the right UDL vertical loading.
- Enter **71.5** again for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis.
- Enter **248.5** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis.
- Enter **Braking SW/2 (Right UDL)** for the **Loading Type** in the next row of loading.
- Enter **1** in the **Track Selection to be Loaded** since there is only a single track in the analysis.
- Enter **3.5** for the **Parametric Starting Position for Loadings** (in m) to indicate the left-hand limit of the right UDL braking loading.
- Enter **28.5** for the **Parametric End Position for Loadings** (in m) to indicate the right-hand limit of the right UDL braking loading.
- Enter **35** for the **Amount (per unit length)** to apply 35 kN/m horizontal braking forces acting to the right for the SW/0 trainset moving from left to right.
- Enter **71.5** again for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis.
- Enter **248.5** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis.

This completes the definition for the SW/2 trainset loading in Train Loading Group 2.

HSLM-A1 trainset loading

The final Train Loading Group is for the HSLM-A1 trainset which is a much more complex trainset configuration involving multiple concentrated loads.

Note. The loading input for the track-structure interaction analysis takes the form of UDLs but a concentrated load can be approximated, especially with the scale of the modelling, by a UDL over a small contact length. This is used to model the concentrated loads which define the HSLM-A1 trainset configuration. For the definition of each of the concentrated loads a contact length of 0.01 m is used to convert the concentrated load into an equivalent UDL. This means that the 170 kN concentrated load becomes a 17000 kN/m UDL applied to this 0.01 m contact length.

The HSLM-A1 trainset configuration consists of 50 concentrated loads which each need to be defined in Train Loading Group 3. To define each of these manually would be a long process and therefore a separate XLSX spreadsheet is provided which includes the definition of the HSLM-A1 trainset using this equivalent UDL approach with the origin of the loading at the centre of the trainset definition.

Note. For a list of assumptions made in defining HSLM-A1 trainset loading (as used to define values in the supplied spreadsheet for use with this example) please see Appendix B of the Rail Track Analysis User Manual. Assumptions made to derive values in this supplied spreadsheet need to be considered for each project individually, and the supplied spreadsheet should not be used as-is without checking the data within it is suitable for use on your project.

- Load the **HSLM-A1.xlsx** spreadsheet in Microsoft Excel or an equivalent application.
- Select all the braking load definition for the HSLM-A1 trainset as indicated below and copy it to the clipboard.

Vertical (Left power car axle 1)

This TAB delimited file defines the HSLM-A1 train definitions for a braking train travelling in the positive (to the right) direction in the RTA model and an accelerating train travelling in the negative (to the left) direction in the RTA model.

The vertical and braking loads for the braking train are defined first, followed by the vertical and traction loads for the accelerating train.
After importing into Microsoft Excel the appropriate loads for the analysis being considered can be copied and pasted into the input spreadsheet.

Contact length for point/axle loads = 0.01
Origin for loading is the middle of the trainset.

BRAKING HSLM-A1 TRAIN

Vertical (Left power car axle 1)	TrackID	-198.7675	-198.7575	17000
Vertical (Left power car axle 2)	TrackID	-195.7675	-195.7575	17000
Vertical (Left power car axle 3)	TrackID	-184.7675	-184.7575	17000
Vertical (Left power car axle 4)	TrackID	-181.7675	-181.7575	17000
Vertical (Left end coach axle 1)	TrackID	-178.2425	-178.2325	17000
Vertical (Left end coach axle 2)	TrackID	-176.2425	-176.2325	17000
Vertical (Left end coach axle 3)	TrackID	-163.005	-162.995	17000
Vertical (Int. coach 1 axle 1)	TrackID	-161.005	-160.995	17000
Vertical (Int. coach 1 axle 2)	TrackID	-145.005	-144.995	17000
Vertical (Int. coach 2 axle 1)	TrackID	-143.005	-142.995	17000
Vertical (Int. coach 2 axle 2)	TrackID	-127.005	-126.995	17000
Vertical (Int. coach 3 axle 1)	TrackID	-125.005	-124.995	17000
Vertical (Int. coach 3 axle 2)	TrackID	-109.005	-108.995	17000
Vertical (Int. coach 4 axle 1)	TrackID	-107.005	-106.995	17000
Vertical (Int. coach 4 axle 2)	TrackID	-91.005	-90.995	17000
Vertical (Int. coach 5 axle 1)	TrackID	-89.005	-88.995	17000
Vertical (Int. coach 5 axle 2)	TrackID	-73.005	-72.995	17000
Vertical (Int. coach 6 axle 1)	TrackID	-71.005	-70.995	17000
Vertical (Int. coach 6 axle 2)	TrackID	-55.005	-54.995	17000
Vertical (Int. coach 7 axle 1)	TrackID	-53.005	-52.995	17000
Vertical (Int. coach 7 axle 2)	TrackID	-37.005	-36.995	17000
Vertical (Int. coach 8 axle 1)	TrackID	-35.005	-34.995	17000
Vertical (Int. coach 8 axle 2)	TrackID	-19.005	-18.995	17000

HSLM-A1

Vertical (Left power car axle 1)

Vertical (Int. coach 9 axle 1)	TrackID	-17.005	-16.995	17000
Vertical (Int. coach 9 axle 2)	TrackID	-1.005	-0.995	17000
Vertical (Int. coach 10 axle 1)	TrackID	0.995	1.005	17000
Vertical (Int. coach 10 axle 2)	TrackID	16.995	17.005	17000
Vertical (Int. coach 11 axle 1)	TrackID	18.995	19.005	17000
Vertical (Int. coach 11 axle 2)	TrackID	34.995	35.005	17000
Vertical (Int. coach 12 axle 1)	TrackID	36.995	37.005	17000
Vertical (Int. coach 12 axle 2)	TrackID	52.995	53.005	17000
Vertical (Int. coach 13 axle 1)	TrackID	54.995	55.005	17000
Vertical (Int. coach 13 axle 2)	TrackID	70.995	71.005	17000
Vertical (Int. coach 14 axle 1)	TrackID	72.995	73.005	17000
Vertical (Int. coach 14 axle 2)	TrackID	88.995	89.005	17000
Vertical (Int. coach 15 axle 1)	TrackID	90.995	91.005	17000
Vertical (Int. coach 15 axle 2)	TrackID	106.995	107.005	17000
Vertical (Int. coach 16 axle 1)	TrackID	108.995	109.005	17000
Vertical (Int. coach 16 axle 2)	TrackID	124.995	125.005	17000
Vertical (Int. coach 17 axle 1)	TrackID	126.995	127.005	17000
Vertical (Int. coach 17 axle 2)	TrackID	142.995	143.005	17000
Vertical (Int. coach 18 axle 1)	TrackID	144.995	145.005	17000
Vertical (Int. coach 18 axle 2)	TrackID	160.995	161.005	17000
Vertical (Right end coach axle 1)	TrackID	162.995	163.005	17000
Vertical (Right end coach axle 2)	TrackID	176.2325	176.2425	17000
Vertical (Right end coach axle 3)	TrackID	178.2325	178.2425	17000
Vertical (Right power car axle 1)	TrackID	181.7575	181.7675	17000
Vertical (Right power car axle 2)	TrackID	184.7575	184.7675	17000
Vertical (Right power car axle 3)	TrackID	195.7575	195.7675	17000
Vertical (Right power car axle 4)	TrackID	198.7575	198.7675	17000
Braking	TrackID	-198.7625	198.7625	15.09339035

Braking load UDL has been factored as total load over the 397.525 m trainset is 7950.5 kN (> 6000 kN limit for default UDL)
Braking load UDL reduced to = 15.093390352808 kN/m

ACCELERATING HSLM-A1 TRAIN

HSLM-A1

- Select the **Loading Type** cell in the first row of the definition of Train Loading Group 3 and choose **Paste Values** to paste all of the HSLM-A1 concentrated loads and braking loads.

The full definition of the HSLM-A1 trainset has been pasted into Train Loading Group 3 with the **Track Selection to be Loaded** set to **TrackID** to indicate that this should be changed. For other models with more than one track this could be set to a track other than Track 1 but for this example we only have a single track.

- For all of the rows of data change the **TrackID** to **1** to apply the HSLM-A1 trainset to the single track in the model.

Enter the following values for the remaining definition of the HSLM-A1 trainset:

- Enter **5** for the **Number of Track Loading Locations** for the passage of the HSLM-A1 trainset from the left-hand abutment to the right-hand abutment. This is a low value for example purposes, and a true analysis would require more locations to fully describe the passage of the trainset loading across the structure.

- Enter **-98.7675** in the first row for the **Starting Location of Loading for First Analysis** to place the trainset in a location where it is just about to enter the deck structure for the first analysis (locations are defined from the left-hand extent of the model including the embankment). The HSLM-A1 trainset has a total length of 397.535 m, 198.7675 m either side of the origin, and accounting for the 100 m long left-hand approach embankment to the left-hand abutment, a value of (100 - 198.7675) = -98.7675 m will place the front of the HSLM-A1 trainset at the left-hand abutment.

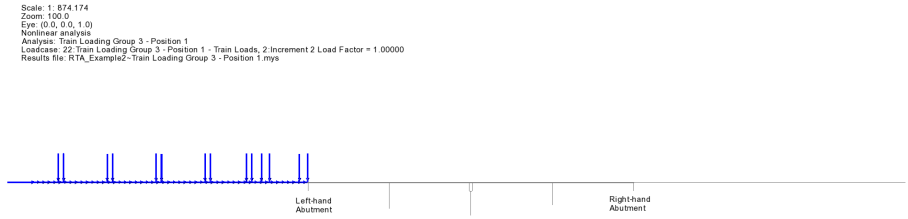
- Enter **418.7675** for the **Finishing Location of Loading for Last Analysis** to place the trainset in a location where it has just departed from the deck structure at the right-hand abutment for the last analysis (locations are defined from the left-hand extent of the model including the embankment). As above, the right-hand abutment location is the sum of the length of the left-hand approach embankment (100 m) and the length of the structure (120 m) and equal to 220 m. The original of the HSLM-A1 train needs to be placed 198.7675 m further on from the right-hand abutment giving a value of (100 + 120 + 198.7675) = 418.7675 m.

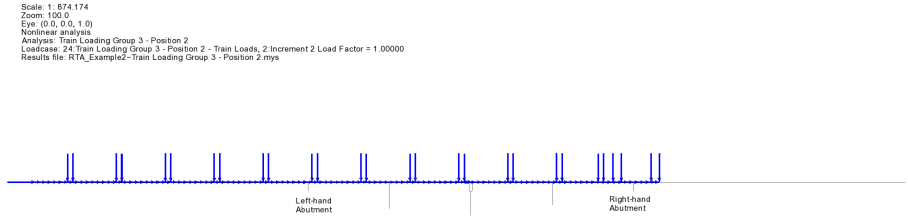
- Select and copy the **Starting Location of Loading for First Analysis** and **Finishing Location of Loading for Last Analysis** entered in the first row.

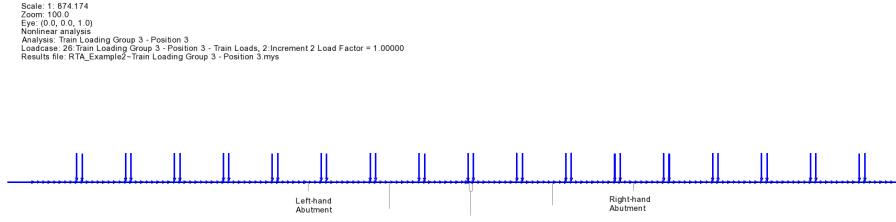
- Select the **Starting Location of Loading for First Analysis** and **Finishing Location of Loading for Last Analysis** cells from rows 16 to 65 in the worksheet and **Paste Values** to paste the locations into all of the rows defining the HSLM-A1 trainset.

- **Save** the spreadsheet and close the Microsoft Excel (or equivalent) application.

Note. The loading for the HSLM-A1 trainset (Train Loading Group 3) is a total of 397.535 m long which is greater than the approach embankment lengths of 100 m and also greater than the overall model length of 320 m. As a consequence of this some proportion of the trainset loading will always be outside the extents of the model for any positioning of the trainset. Loading outside the extents of the model will be ignored in the analyses and a warning will be displayed when the trainset loading is being applied to the model. This is illustrated in the images that follow, which show the positioning of the HSLM-A1 trainset for the first three analysis locations.







This completes the definition of the spreadsheet input for track-structure interaction problem.

Modelling / Running an Analysis

All of the model construction and analysis is automatically performed by the Rail Track Analysis software option but, to do so, a blank LUSAS model must be initially created or a suitable existing LUSAS model (that was created by the Rail Track Analysis option) must be opened.

Running LUSAS Modeller

For details of how to run LUSAS Modeller, see the heading ***Running LUSAS Modeller*** in the *Introduction to LUSAS Worked Examples* document.

Creating the Combined Temperature and Rail Load Model

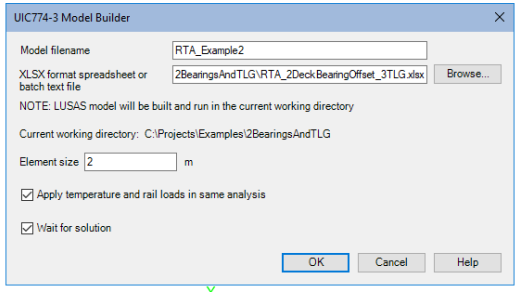
An initial temperature-only analysis can form the basis for carrying out more than one track-structure interaction analysis with different trainset loading configurations in different input spreadsheets (see the *Rail Track-Structure Interaction to UIC774-3* worked example). If Train Loading Groups are not used then this could be the approach to follow for the current analysis but since we are including three Train Loading Groups (1 = SW/0 loading, 2 = SW/2 loading and 3 = HSLM-A1 loading) we can generate the combined temperature and rail loading model for this example.

File
New…

- Enter **RTA_BlankModel** for the model name.
- Select an analysis category of **3D** and click **OK**.

This model is created solely to allow the Rail Track Analysis option to be selected. It is not used after the option has been run.

Bridge
Rail Track Analysis >
Build UIC774-3 Model…



- Enter a model filename of **RTA_Example2**
- Enter the filename of the XLSX spreadsheet you created which contains the definition of the track-structure interaction model and the loading to be applied in the Rail Track Analysis (e.g. **RTA_2DeckBearingOffset_3TLG.xlsx**) or browse for it using the **Browse...** button in the XLSX format spreadsheet or batch text file. If the full folder information is not entered it will be assumed that the XLSX spreadsheet is in the current working folder which is reported in the dialog.

- If wanting to build the model from a supplied spreadsheet, select the file **RTA_2DeckBearingOffset_3TLG.xlsx** that was downloaded and placed in a folder of your choosing.

- Ensure an Element size of **2** is specified which will create elements of a maximum length of 2 m in the LUSAS model.
- Ensure that the **Apply temperature and rail loads in same analysis** option is selected.
- Ensure the **Wait for solution option** is selected and click the **OK** button.
- Click **Yes** to continue when a dialog pops up warning that loading has been defined which is outside the extent of the model. The HSLM-A1 trainset is almost 400 m long and therefore an equivalent embankment length would be required to accommodate the whole trainset as it approaches and departs from the structure. In the model embankments of only 100 m have been used with an overall model length of 320 m including the structure and therefore the load outside the extents of the model will be ignored for HSLM-A1 trainset loading that is not fully within a model.

Assuming that there have been no errors in the input for the XLSX spreadsheet the Rail Track Analysis software option will automatically generate a LUSAS model from the spreadsheet data and run a rail track analysis for the combined temperature and rail loading.

If the Rail Track Analysis software option detected errors with modelling data these will be reported and must be corrected prior to re-running the Rail Track Analysis option.

If errors were detected...

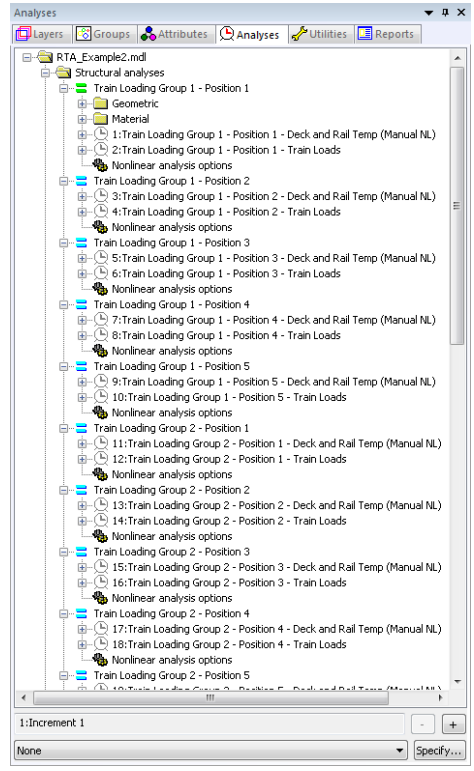
If errors were detected with the modelling data, or the post-processing in the next section gives different results, the values in the spreadsheet should be corrected before re-selecting the previous Rail Track Analysis menu item. If it proves impossible for you to correct the errors reported a populated spreadsheet file is provided to enable you to create the model and run an analysis successfully.

- **RTA_2DeckBearingOffset_3TLG.xlsx** is a populated spreadsheet containing all input data for the example.

The spreadsheet should be copied to the working project folder where the track-structure interaction example model is to be created, and the **Bridge > Rail Track Analysis UIC774-3 > Apply Rail Loads** menu item re-selected.

Viewing the Results

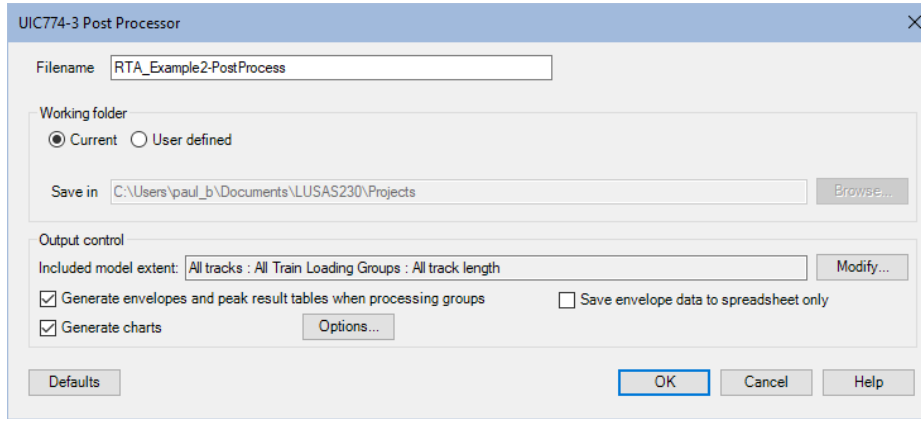
When the results are loaded after carrying out the Rail Track Analysis the Treeview will be populated with all of the positions for each of the Train Loading Groups with each as a separate analysis as indicated in the following figure.



Automatic Extraction of Results into an Excel Spreadsheet

The Rail Track Analysis option provides a post-processing tool that automatically extracts the results of all of the analyses (all positions of all Train Loading Groups) into tabular form to a Microsoft Excel XLSX format spreadsheet and generates commonly required graphs and tables of quantities that can be compared against prescribed limits for the track-structure interaction.

Bridge
Rail Track Analysis >
Extract Results to Excel…



- Enter **RTA_Example2-PostProcess** for the **Filename**. Note that no *.xlsx extension is required.
- Ensure the **Working folder** is set to **Current** to place the post-processing spreadsheet into the same folder as the analyses.
- Ensure the **Output Control** is reporting that "**All tracks : All Train Loading Groups : All track length**" are included in the model extent.

For a new model being post-processed for the first time this should always be the case. If previous selective post-processing has been carried out on the model and the model saved that choice will have been stored for use again by the post-processor. The included model extent must be updated by clicking the **Modify** button and revising the selection. Clicking the **Defaults** button in the **Modify Included Output** dialog will return the included model extent to "All tracks : All Train Loading Groups : All track length" if needed.

- Ensure the **Output Control** is reporting that the **Generate envelopes and peak result tables when processing groups** option is selected.
- Ensure the **Output Control** is reporting that the **Generate charts** option is selected.

If previous customised post-processing has been carried out on the model and the model saved the choice of charts created may have been changed from the defaults and will have been stored for use again by the post-processor. The choice of charts created must be updated by clicking the **Options** button and the included charts revised. Clicking the **Defaults** button in the **Chart Options** dialog will return the chart options to the defaults.

- Click the **OK** button.

The automatic Rail Track Analysis post-processor will now extract the results from the loaded analyses results and generate the spreadsheet in the working folder.

Note. The post-processing for this example will take less than 30 seconds. For much larger Rail Track Analyses (larger structures with more tracks / more train positions / group considerations) an estimate of the time to complete the post-processing for each worksheet can be obtained by watching the progress bar at the bottom of the Modeller window. Post-processing of all the results will occupy the LUSAS licence for the time that the post-processing is being carried out.

- Open the spreadsheet **RTA_Example2-PostProcess** in Microsoft Excel (or an equivalent application).

Since the creation of envelopes was specified earlier the results spreadsheet will contain eleven worksheets that contain the results from the analyses. Note that some spreadsheet applications may only show the tabs for the last created worksheets and hide the previous worksheets. If this is the case, other worksheets can typically be seen by pressing the 'back' arrow at the bottom of the worksheet window.

The worksheets created are titled:

- **Track 1**
- **Decks**
- **Envelope – Track 1**
- **Envelope – Decks**
- **Railbed Check**
- **Deck Long. Gap Check-Axial**
- **Deck Long. Gap Check-End Rot.**
- **Deck Long. Gap Check-Total**
- **Deck Vertical Gaps Check**
- **Longitudinal Reactions Check**
- **Rail Stresses Check**

The enveloping in the **Envelope – Track 1** and **Envelope – Decks** will be over the analyses of all of the Train Loading Groups and their respective positions.

The **Deck Long. Gap Check-Axial**, **Deck Long. Gap Check-End Rot.**, **Deck Long. Gap Check-Total** and **Deck Vertical Gaps Check** are additional tables of peak results required by UIC774-3 which are present because there is more than one deck in the analysis (the example which replicates the UIC774-3 E1-3 and E4-6 fundamental tests only had a single deck and therefore these results were not available). The **Deck Long. Gap Check** worksheets list the peak gap opening and closing in the longitudinal direction between the ends of neighbouring decks or the abutment for axial effects, end

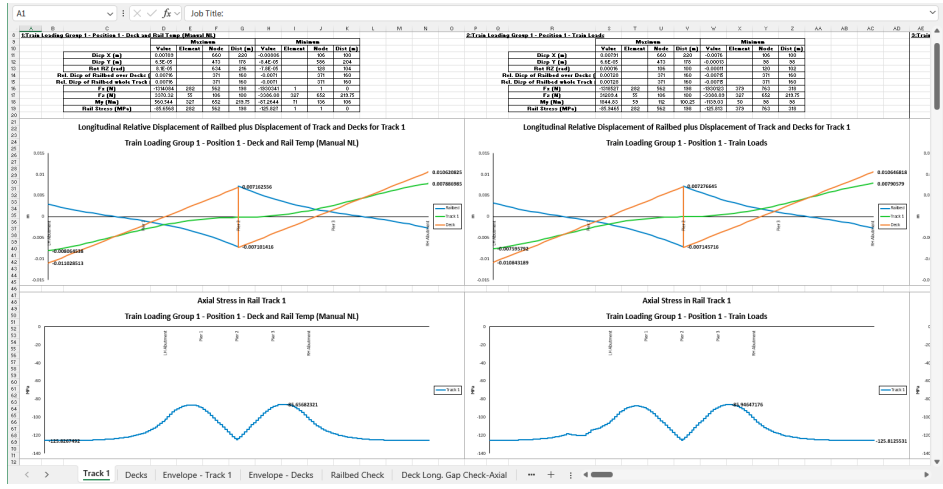
rotation effects and total combined effects of the two. Similarly, the **Deck Vertical Gaps Check** worksheet lists the peak vertical movement between the ends of neighbouring decks or the abutment.

Overall Displacement and Stress Behaviour of Railtrack

The overall behaviour of the track-structure model can be inspected through the **Track 1** and **Decks** worksheets which provide the raw data from the analyses along with summary tables and useful charts.

- Click on the **Track 1** worksheet tab.

For each Train Loading Group and associated position the worksheet will contain the results for the temperature effects alone and also the combined temperature and rail loading as indicated below for position 1 of Train Loading Group 1 (SW/0 loading). The summary table at the top provides key information such as the peak displacements of the track, the peak relative railbed displacements, the forces and moments in the track and the axial stresses in the track for each set of results.



The displacement chart overlays the longitudinal displacement results of the track (in green) and the deck (in orange) with the relative railbed displacement occurring from these also displayed (in blue). Large discontinuities (jumps) observed in these deck and relative railbed displacement results correlate with the discontinuities of decks in the structure. Discontinuities may also be seen in the results of the track longitudinal displacements for some analyses if expansion joints are present within the length of the structure (this is not the case for this model, the expansion joints are at the left-hand and right-hand abutments).

The rail axial stress chart shows the rail stresses observed in the railtrack over the full extent of the model. Should the model include more than one track then an additional

chart displaying the rail stresses for all tracks may also be shown if this has been selected in the charting options.

Similar raw results and charts are contained in the **Decks** worksheet which provides displacements, forces and moments for the members of the decks.

In addition to the raw results of the track-structure interaction analyses, because of the selection to generate envelopes earlier this also makes the post-processor evaluate and report similar enveloped results over all of the Train Loading Groups and positions. Six envelopes are generated by the post-processor, namely:

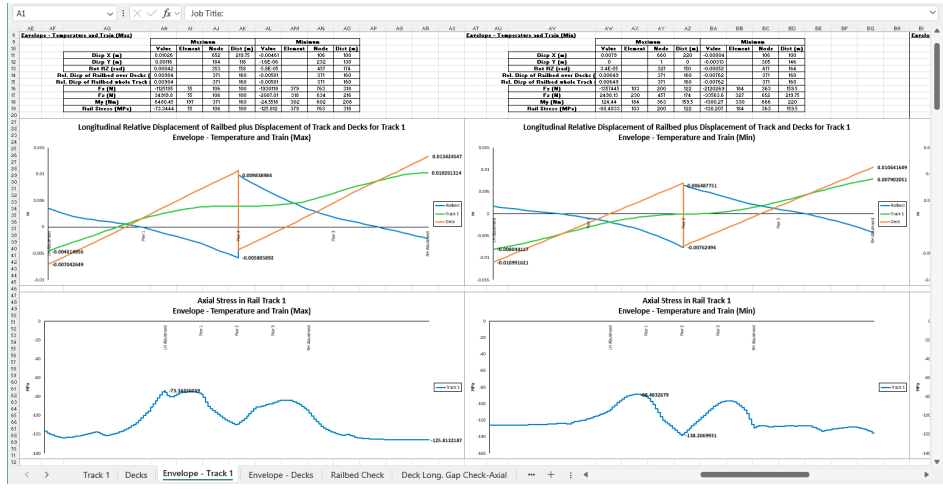
- **Envelope - Temperature Only (Max)**
- **Envelope - Temperature Only (Min)**
- **Envelope - Temperature and Train (Max)**
- **Envelope - Temperature and Train (Min)**
- **Envelope - All Configurations (Max)**
- **Envelope - All Configurations (Min)**

Note. The **All Configurations** envelope provides an envelope over all loading configurations that are present in the analysis which in this case is temperature only and combined temperature and train loading. If valid basic combinations were also present an additional maximum / minimum envelope would be presented for these results and the results from these basic combinations would be included within the **All Configurations** envelope.

The summaries and charts are displayed for the **Envelope – Temperature and Train (Max)** and **Envelope – Temperature and Train (Min)** results in the following image.

- Click on the **Envelope - Track 1** worksheet tab.

Within the summary tables and charts, it indicates that the maximum positive relative railbed displacement observed over all Train Loading Groups in the analysis is +0.00984 m (or 9.84 mm) and the minimum negative relative railbed displacement is -0.00762 m (or -7.62 mm), an absolute maximum value of 0.00984 m (or 9.84 mm). Similarly, the most tensile axial rail stress is -73.34 MPa and the most compressive axial rail stress is -138.21 MPa. These results will be revisited later on through the tables of peak results.



Peak Relative Railbed Displacement

The previous section obtained the peak relative railbed displacements over all Train Loading Groups and positions. The post-processor also provides tabular peak results for each of the Train Loading Groups and positions in the **Railbed Check** worksheet.

- Click on the **Railbed Check** worksheet tab.

The table indicates from the highlighted row that the absolute maximum value of relative railbed displacement occurs in Train Loading Group 2 when the SW/2 loading is at the second position. The value of the relative railbed displacement is +0.00984 m (+9.84 mm) which occurs 60 m from the left end of the structure, which is at Pier 2, the pier that supports both deck 1 and 2. This value agrees with the value reported in the summary table previously but also tells us the precise trainset loading configuration and positioning of that trainset which causes the worst case along with a better description of where the peak is occurring.

Check of Longitudinal Relative Displacement of Railbed (Relative Displacement between Rails and Deck)

Job Title: UIC 774-3 Model: RTA_Example2
Analysis Filename: RTA_Example2~Train Loading Group 1 - Position 1 --> RTA_Example2~Train Loading Group 3 - Position 5
Model Directory: C:\Projects\Examples\2BearingsAndTLG
Analysis Date: 26/11/2024 --> 26/11/2024
Model Units: N,m,kg,s,C

Analysis ID	Results Filename	Loading Type	Track 1: Distance from Left End of the Model to the Starting Position of the Loading (m)	Track 1: Distance from Left End of the Model to the Finishing Position of the Loading (m)	Peak Relative Longitudinal Displacement between Rail and Slab (m)	Track Number with Peak Displacement	Distance from Left End of Structure for Peak Displacement (m)	Description of peak location
1	RTA_Example2~Train Loading Group 1 - Position 1.mys	Temperature Only			0.007162556	1	60	Pier 2
1	RTA_Example2~Train Loading Group 1 - Position 1.mys	Braking	64.7	100	0.007276645	1	60	Pier 2
2	RTA_Example2~Train Loading Group 1 - Position 2.mys	Braking	103.525	138.825	0.008242724	1	60	Pier 2
3	RTA_Example2~Train Loading Group 1 - Position 3.mys	Braking	142.35	177.65	0.00761531	1	60	Pier 2
4	RTA_Example2~Train Loading Group 1 - Position 4.mys	Braking	181.175	216.475	0.006835571	1	60	Pier 2
5	RTA_Example2~Train Loading Group 1 - Position 5.mys	Braking	220	255.3	0.007112981	1	60	Pier 2
6	RTA_Example2~Train Loading Group 2 - Position 1.mys	Braking	25	125	0.007252626	1	60	Pier 2
7	RTA_Example2~Train Loading Group 2 - Position 2.mys	Braking	87.25	144.25	0.009818984	1	60	Pier 2
8	RTA_Example2~Train Loading Group 2 - Position 3.mys	Braking	131.5	188.5	0.008235007	1	60	Pier 2
9	RTA_Example2~Train Loading Group 2 - Position 4.mys	Braking	175.75	232.75	0.006487751	1	60	Pier 2
10	RTA_Example2~Train Loading Group 2 - Position 5.mys	Braking	220	277	0.007070072	1	60	Pier 2
11	RTA_Example2~Train Loading Group 3 - Position 1.mys	Braking	-298.7675	98.7675	0.007253956	1	60	Pier 2
12	RTA_Example2~Train Loading Group 3 - Position 2.mys	Braking	-168.7675	228.7675	0.007770173	1	60	Pier 2
13	RTA_Example2~Train Loading Group 3 - Position 3.mys	Braking	-38.7675	358.7675	0.007770409	1	60	Pier 2
14	RTA_Example2~Train Loading Group 3 - Position 4.mys	Braking	91.2325	488.7675	0.007753889	1	60	Pier 2
15	RTA_Example2~Train Loading Group 3 - Position 5.mys	Braking	221.2325	618.7675	0.007124823	1	60	Pier 2

Track 1 | Decks | Envelope - Track 1 | Envelope - Decks | Railbed Check | Deck Long. Gap Check-Axial | Deck

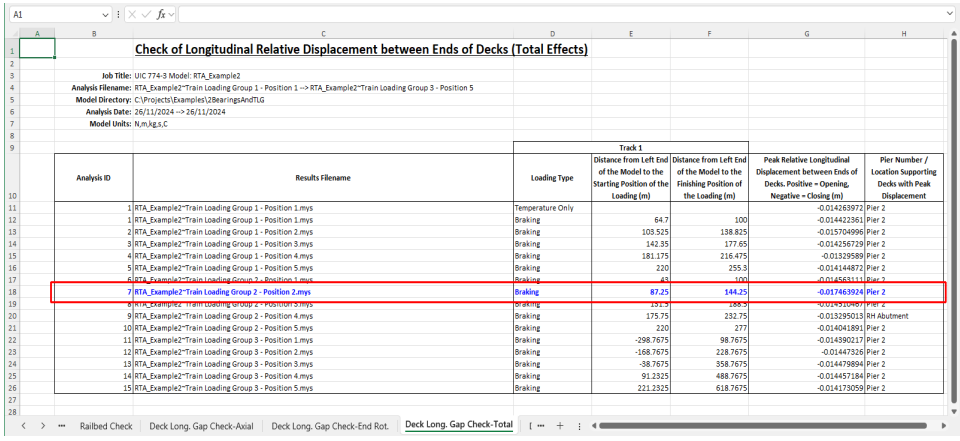
Peak Longitudinal Displacements Between Deck Ends / Abutments

The movement / opening and closing of gaps between the ends of decks / abutments needs to be considered within UIC774-3 and to assist with this the post-processor automatically calculates these quantities if enveloping has been selected in the post-processing.

Results are provided for axial effects alone in the **Deck Long. Gap Check-Axial** worksheet, end rotation effects alone in the **Deck Long. Gap Check-End Rot.** worksheet and total (combined) effects of both axial and end rotation in the **Deck Long. Gap Check-Total** worksheet. For this example, we are only looking at the total (combined) effects.

- Click on the **Deck Long. Gap Check-Total** worksheet tab.

The table indicates from the highlighted row that the absolute maximum value of deck end gap movement is -0.0175 m (-17.5 mm) closure of the gap between decks 1 and 2 at Pier 2 in Train Loading Group 2 when the SW/2 loading is at the second position.



Check of Longitudinal Relative Displacement between Ends of Decks (Total Effects)

Job Title: UIC 774-3 Model: RTA_Example2
Analysis Filename: RTA_Example2~Train Loading Group 1 - Position 1 --> RTA_Example2~Train Loading Group 3 - Position 5
Model Directory: C:\Projects\Examples\2BearingsAndTLG
Analysis Date: 26/11/2024 --> 26/11/2024
Model Units: N,m,kg,s,C

Analysis ID	Results Filename	Loading Type	Track 1: Distance from Left End of the Model to the Starting Position of the Loading (m)	Track 1: Distance from Left End of the Model to the Finishing Position of the Loading (m)	Peak Relative Longitudinal Displacement between Ends of Decks. Positive = Opening, Negative = Closing (m)	Pier Number / Location Supporting Decks with Peak Displacement
1	RTA_Example2~Train Loading Group 1 - Position 1.mys	Temperature Only			-0.014263972	Pier 2
1	RTA_Example2~Train Loading Group 1 - Position 1.mys	Braking	64.7	100	-0.014422361	Pier 2
2	RTA_Example2~Train Loading Group 1 - Position 2.mys	Braking	103.525	138.825	-0.015704996	Pier 2
3	RTA_Example2~Train Loading Group 1 - Position 3.mys	Braking	142.35	177.65	-0.014256729	Pier 2
4	RTA_Example2~Train Loading Group 1 - Position 4.mys	Braking	181.175	216.475	-0.01329589	Pier 2
5	RTA_Example2~Train Loading Group 1 - Position 5.mys	Braking	220	255.3	-0.014144872	Pier 2
6	RTA_Example2~Train Loading Group 2 - Position 1.mys	Braking	43	100	-0.014563111	Pier 2
7	RTA_Example2~Train Loading Group 2 - Position 2.mys	Braking	87.25	144.25	-0.017463924	Pier 2
8	RTA_Example2~Train Loading Group 2 - Position 3.mys	Braking	131.5	188.5	-0.014510465	Pier 2
9	RTA_Example2~Train Loading Group 2 - Position 4.mys	Braking	175.75	232.75	-0.013295013	RH Abutment
10	RTA_Example2~Train Loading Group 2 - Position 5.mys	Braking	220	277	-0.014041891	Pier 2
11	RTA_Example2~Train Loading Group 3 - Position 1.mys	Braking	-298.7675	98.7675	-0.014390217	Pier 2
12	RTA_Example2~Train Loading Group 3 - Position 2.mys	Braking	-168.7675	228.7675	-0.01447326	Pier 2
13	RTA_Example2~Train Loading Group 3 - Position 3.mys	Braking	-38.7675	358.7675	-0.014479894	Pier 2
14	RTA_Example2~Train Loading Group 3 - Position 4.mys	Braking	91.2325	488.7675	-0.014457184	Pier 2
15	RTA_Example2~Train Loading Group 3 - Position 5.mys	Braking	221.2325	618.7675	-0.014173059	Pier 2

Railbed Check | Deck Long. Gap Check-Axial | Deck Long. Gap Check-End Rot. | Deck Long. Gap Check-Total

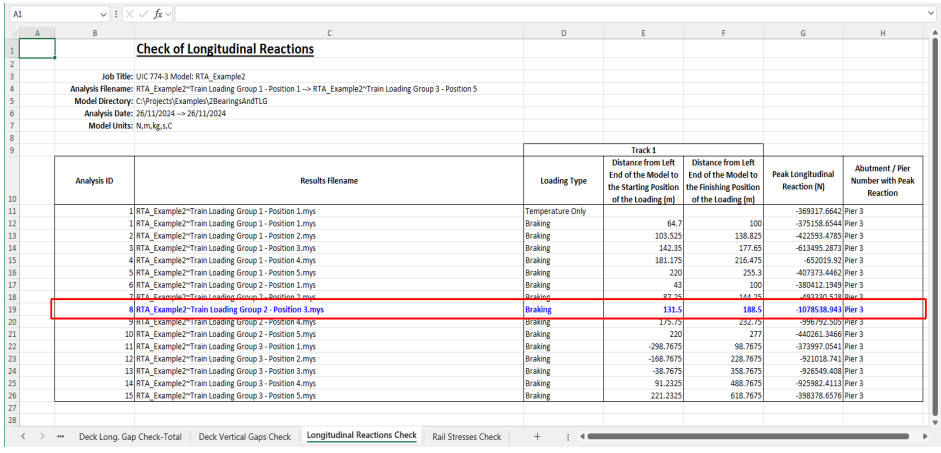
Peak Longitudinal Reactions at the Piers and Abutments

The intermediate piers for each deck provide all of the longitudinal restraint to each of the decks of the structure and the peak longitudinal reactions at these piers are now investigated.

When post-processing, the option to create the envelopes was chosen which caused an additional worksheet tabulating the peak longitudinal reactions for all of the analyses to be created.

- Click on the **Longitudinal Reactions Check** worksheet tab.

The table indicates from the highlighted row that the absolute maximum value of longitudinal reaction is -1078539 N (or -1.078539 MN) at Pier 3 (the intermediate pier in Deck 2) in Train Loading Group 2 when the SW/2 loading is at the third position.



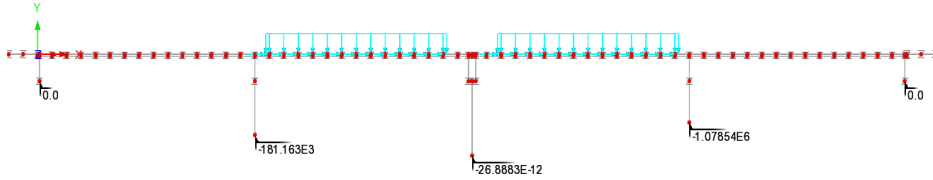
Check of Longitudinal Reactions

Job Title: UIC 774-3 Model: RTA_Example2
Analysis Filename: RTA_Example2~Train Loading Group 1 - Position 1 --> RTA_Example2~Train Loading Group 3 - Position 5
Model Directory: C:\Projects\Examples\2BearingsAndTLG
Analysis Date: 26/11/2024 --> 26/11/2024
Model Units: N,m,kg,s,C

Analysis ID	Results Filename	Loading Type	Track 1: Distance from Left End of the Model to the Starting Position of the Loading (m)	Track 1: Distance from Left End of the Model to the Finishing Position of the Loading (m)	Peak Longitudinal Reaction (N)	Abutment / Pier Number with Peak Reaction
1	RTA_Example2~Train Loading Group 1 - Position 1.mys	Temperature Only			-369317.6642	Pier 3
1	RTA_Example2~Train Loading Group 1 - Position 1.mys	Braking	64.7	100	-375158.6544	Pier 3
2	RTA_Example2~Train Loading Group 1 - Position 2.mys	Braking	103.525	138.825	-422593.4785	Pier 3
3	RTA_Example2~Train Loading Group 1 - Position 3.mys	Braking	142.35	177.65	-613495.2873	Pier 3
4	RTA_Example2~Train Loading Group 1 - Position 4.mys	Braking	181.175	216.475	-652019.92	Pier 3
5	RTA_Example2~Train Loading Group 1 - Position 5.mys	Braking	220	255.3	-407373.4462	Pier 3
6	RTA_Example2~Train Loading Group 2 - Position 1.mys	Braking	43	100	-380412.1949	Pier 3
7	RTA_Example2~Train Loading Group 2 - Position 2.mys	Braking	87.25	144.25	-493330.578	Pier 3
8	RTA_Example2~Train Loading Group 2 - Position 3.mys	Braking	131.5	188.5	-1078538.943	Pier 3
9	RTA_Example2~Train Loading Group 2 - Position 4.mys	Braking	175.75	232.75	-396782.505	Pier 3
10	RTA_Example2~Train Loading Group 2 - Position 5.mys	Braking	220	277	-440261.3466	Pier 3
11	RTA_Example2~Train Loading Group 3 - Position 1.mys	Braking	-298.7675	98.7675	-373997.0541	Pier 3
12	RTA_Example2~Train Loading Group 3 - Position 2.mys	Braking	-168.7675	228.7675	-921018.741	Pier 3
13	RTA_Example2~Train Loading Group 3 - Position 3.mys	Braking	-38.7675	358.7675	-926549.408	Pier 3
14	RTA_Example2~Train Loading Group 3 - Position 4.mys	Braking	91.2325	488.7675	-925982.4113	Pier 3
15	RTA_Example2~Train Loading Group 3 - Position 5.mys	Braking	221.2325	618.7675	-398378.6576	Pier 3

Deck Long. Gap Check-Total | Deck Vertical Gaps Check | Longitudinal Reactions Check | Rail Stresses Check

Note. Should the reactions at any other support / Train Loading Group / position be required from the analysis rather than just the peak values shown in the table then these can simply be obtained through normal post-processing methods in Modeller. This is illustrated below for "Train Loading Group 2 – Position 3" which shows an identical result of -1.07854E6 N for Pier 3 along with the reactions for the remaining piers and the abutments.

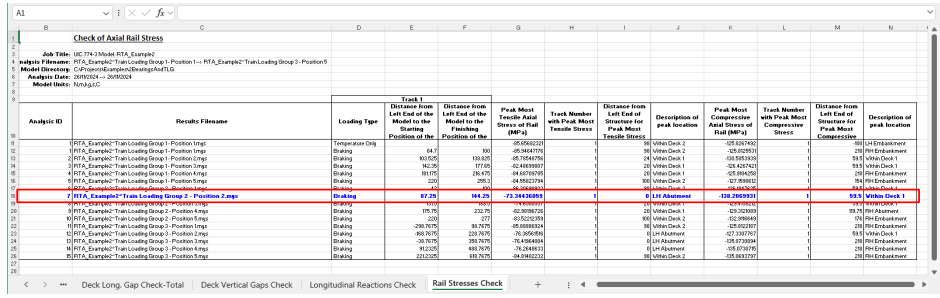


Peak Axial Rail Stresses

The peak axial rail stresses were previously obtained from the raw results in the **Envelope - Track 1** worksheet tab which gave the values of the most tensile axial rail stress as -73.34 MPa and the most compressive axial rail stress as -138.21 MPa. In addition to the raw envelope results in this worksheet tab the post-processor also generates tables of the peak axial rail stresses for each of the Train Loading Groups and positions.

- Click on the **Rail Stresses Check** worksheet tab.

The table indicates from the highlighted row that the most tensile and most compressive axial rail stresses both occur for Train Loading Group 2 when the SW/2 loading is at the second position.

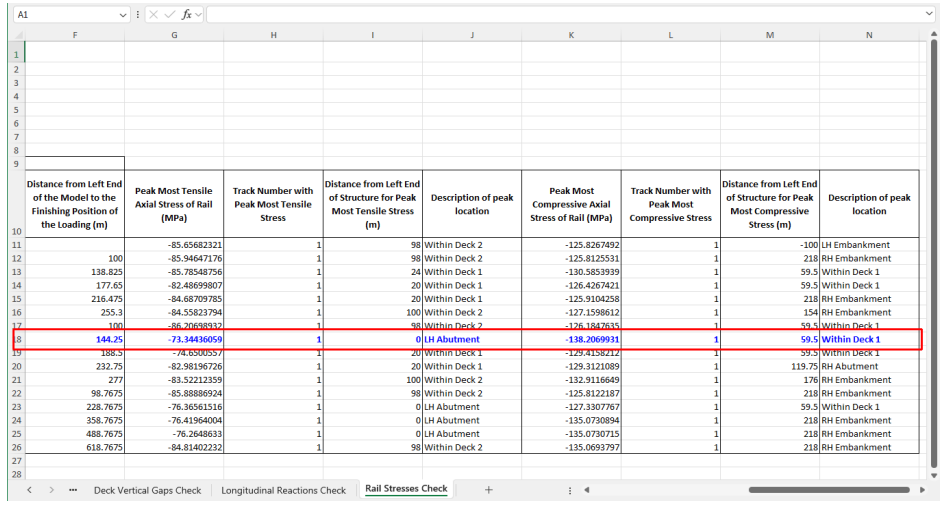


Check of Axial Rail Stress

Job Title: UIC774-3 Model RITA_Example2
Analysis Filename: RITA_Example2~Train Loading Group 1 - Position 1 --> RITA_Example2~Train Loading Group 3 - Position 5
Model Directory: C:\Projects\Examples\BreakingAndTLG
Analysis Date: 26/09/2024 -- 26/09/2024
Model Units: N,m,kg,s,C

Analysis ID	Results Filename	Loading Type	Distance from Left End of the Model to the Starting Position of the	Distance from Left End of the Model to the Finishing Position of the	Peak Most Tensile Axial Stress of Rail (MPa)	Track Number with Peak Most Tensile Stress	Distance from Left End of Structure for Peak Most Tensile Stress	Description of peak location	Peak Most Compressive Axial Stress of Rail (MPa)	Track Number with Peak Most Compressive Stress	Distance from Left End of Structure for Peak Most Compressive	Description of peak location
			Track 1									
1	RITA_Example2~Train Loading Group 1 - Position 1.mgc	Temperature Drop	64.5	180	-85.65682321	1	98	Within Deck 2	-125.8267492	1	-100	LH Embankment
2	RITA_Example2~Train Loading Group 1 - Position 2.mgc	Braking	103.525	139.825	-85.94647176	1	98	Within Deck 2	-125.8125531	1	218	RH Embankment
3	RITA_Example2~Train Loading Group 1 - Position 3.mgc	Braking	142.35	177.65	-82.48699807	1	24	Within Deck 1	-130.5853939	1	59.5	Within Deck 1
4	RITA_Example2~Train Loading Group 1 - Position 4.mgc	Braking	181.175	216.475	-84.68709785	1	20	Within Deck 1	-126.4267421	1	59.5	Within Deck 1
5	RITA_Example2~Train Loading Group 1 - Position 5.mgc	Braking	220	255.3	-84.55823794	1	100	Within Deck 2	-127.1598612	1	218	RH Embankment
6	RITA_Example2~Train Loading Group 2 - Position 1.mgc	Braking	43	100	-86.20698932	1	98	Within Deck 2	-126.1847635	1	59.5	Within Deck 1
7	RITA_Example2~Train Loading Group 2 - Position 2.mgc	Braking	87.25	144.25	-73.34436059	1	0	LH Abutment	-138.2069931	1	59.5	Within Deck 1
8	RITA_Example2~Train Loading Group 2 - Position 3.mgc	Braking	131.5	188.5	-74.65005557	1	20	Within Deck 1	-129.4158212	1	59.5	Within Deck 1
9	RITA_Example2~Train Loading Group 2 - Position 4.mgc	Braking	175.75	232.75	-82.98196726	1	20	Within Deck 1	-129.3121089	1	119.75	RH Abutment
10	RITA_Example2~Train Loading Group 2 - Position 5.mgc	Braking	220	277	-83.52212359	1	100	Within Deck 2	-132.9116649	1	176	RH Embankment
11	RITA_Example2~Train Loading Group 3 - Position 1.mgc	Braking	-230.7675	98.7675	-85.88886924	1	98	Within Deck 2	-125.8122187	1	218	RH Embankment
12	RITA_Example2~Train Loading Group 3 - Position 2.mgc	Braking	-190.7675	228.7675	-76.36561516	1	0	LH Abutment	-127.3307767	1	59.5	Within Deck 1
13	RITA_Example2~Train Loading Group 3 - Position 3.mgc	Braking	-150.7675	358.7675	-76.41964004	1	0	LH Abutment	-135.0730894	1	218	RH Embankment
14	RITA_Example2~Train Loading Group 3 - Position 4.mgc	Braking	-110.7675	488.7675	-76.2648633	1	0	LH Abutment	-135.0730715	1	218	RH Embankment
15	RITA_Example2~Train Loading Group 3 - Position 5.mgc	Braking	-121.2325	618.7675	-84.81402232	1	98	Within Deck 2	-135.0693797	1	218	RH Embankment

Zooming into the results columns (for clarity) it shows that the most tensile axial rail stress is -73.34 MPa which occurs at the left-hand abutment and the most compressive axial rail stress is -138.21 MPa which occurs within Deck 1. These results were observed previously in the summary tables and charts for the **Envelope - Track 1** worksheet tab.



Distance from Left End of the Model to the Finishing Position of the Loading (m)	Peak Most Tensile Axial Stress of Rail (MPa)	Track Number with Peak Most Tensile Stress	Distance from Left End of Structure for Peak Most Tensile Stress (m)	Description of peak location	Peak Most Compressive Axial Stress of Rail (MPa)	Track Number with Peak Most Compressive Stress	Distance from Left End of Structure for Peak Most Compressive Stress (m)	Description of peak location
	-85.65682321	1	98	Within Deck 2	-125.8267492	1	-100	LH Embankment
100	-85.94647176	1	98	Within Deck 2	-125.8125531	1	218	RH Embankment
138.825	-85.78548756	1	24	Within Deck 1	-130.5853939	1	59.5	Within Deck 1
177.65	-82.48699807	1	20	Within Deck 1	-126.4267421	1	59.5	Within Deck 1
216.475	-84.68709785	1	20	Within Deck 1	-125.9104258	1	218	RH Embankment
255.3	-84.55823794	1	100	Within Deck 2	-127.1598612	1	154	RH Embankment
100	-86.20698932	1	98	Within Deck 2	-126.1847635	1	59.5	Within Deck 1
144.25	-73.34436059	1	0	LH Abutment	-138.2069931	1	59.5	Within Deck 1
188.5	-74.6500557	1	20	Within Deck 1	-129.4158212	1	59.5	Within Deck 1
232.75	-82.98196726	1	20	Within Deck 1	-129.3121089	1	119.75	RH Abutment
277	-83.52212359	1	100	Within Deck 2	-132.9116649	1	176	RH Embankment
98.7675	-85.88886924	1	98	Within Deck 2	-125.8122187	1	218	RH Embankment
228.7675	-76.36561516	1	0	LH Abutment	-127.3307767	1	59.5	Within Deck 1
358.7675	-76.41964004	1	0	LH Abutment	-135.0730894	1	218	RH Embankment
488.7675	-76.2648633	1	0	LH Abutment	-135.0730715	1	218	RH Embankment
618.7675	-84.81402232	1	98	Within Deck 2	-135.0693797	1	218	RH Embankment

These values agree with the values reported previously in the enveloping summary table for Track 1 and also provide the precise trainset loading configuration and positioning that caused the worst most tensile and worst most compressive axial stress in the rails along with a description of the locations of where these peaks occurred.

- Close the Microsoft Excel (or equivalent) application.

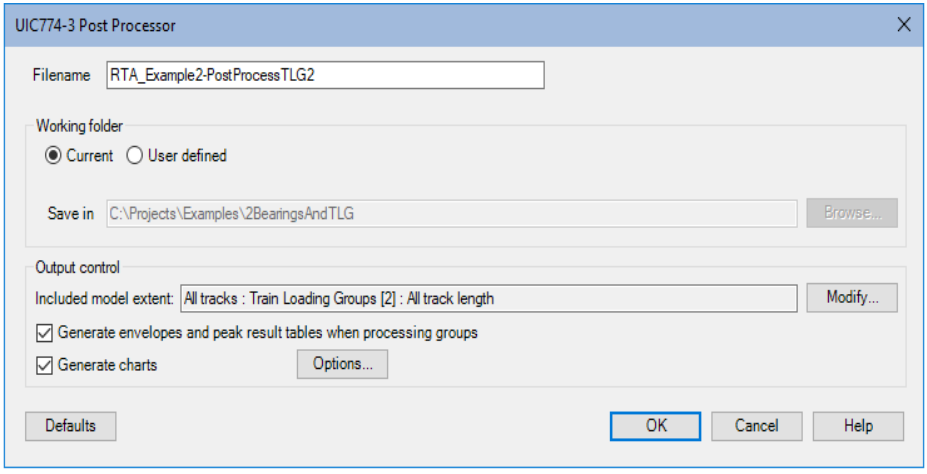
Viewing Results for a Single Train Loading Group

The post-processing that was carried out looked at the behaviour of the model for all three Train Loading Groups that were analysed. If we wished to only generate the output spreadsheet for a limited set of Train Loading Groups (or possibly limited tracks / track length for another model) the extent of the model to be post-processed can be

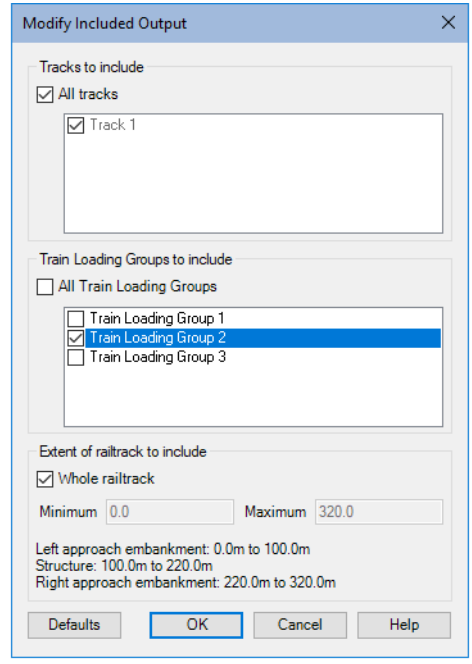
adjusted using the additional output controls available on the post-processor dialog – for full details of how to use all of the facilities within the post-processor, please see the Rail Track User Manual.

For this example, we will demonstrate the basic use of these facilities to post-process the Train Loading Group which gave the worst effects, Train Loading Group 2 which represented the SW/2 loading.

Bridge
Rail Track Analysis >
Extract Results to Excel…



- Enter **RTA_Example2-PostProcessTLG2** for the **Filename**. Note that no *.xlsx extension is required.
- Ensure the **Working folder** is set to **Current** to place the post-processing spreadsheet into the same folder as the analyses.
- Click the **Modify…** button in the **Output control** to change the **Included model extent** from the current selection.
- In the **Modify Included Output** dialog, deselect the **All Train Loading Groups** option.
- Ensure that only **Train Loading Group 2** is selected in the list as shown in the image below.
- Click **OK** button on the **Modify Included Output** dialog to update the included model extent.
- Click the **OK** button on the **UIC774-3 Post Processor** dialog.



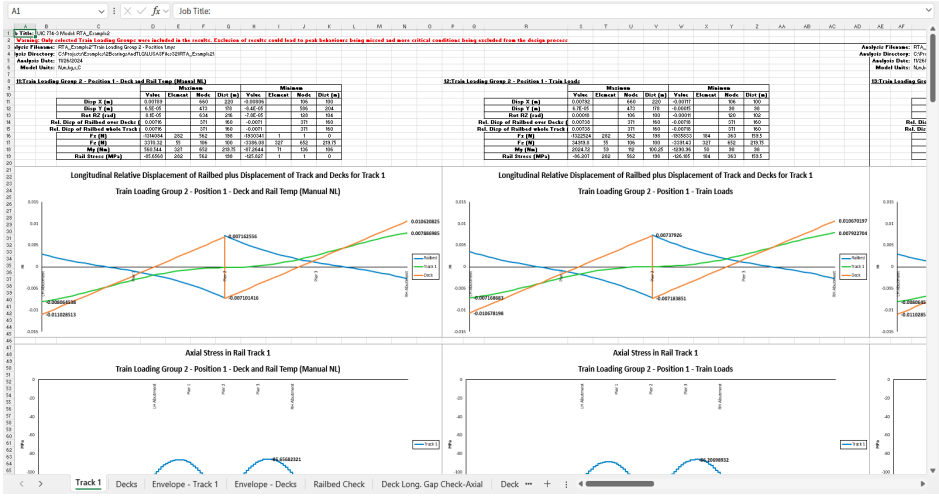
The automatic Rail Track Analysis post-processor will now extract the results from just Train Loading Group 2 (the SW/2 loading) into the output spreadsheet.

Identical results worksheets (Tracks, Decks, Envelopes of Tracks/Decks, Railbed Check, etc) will be generated in the spreadsheet that is created from the post-processor when the output extent is modified but the restriction of the post-processing could mean that peak results / the most onerous behaviours of output quantities are missed in the post-processing as a result of the restricted post-processing. As a result, warning messages will be issued in the spreadsheet when post-processing of the whole model is not carried out.

In the worksheet for the track results shown in the next image the following warning has been placed at the top of the results:

"Warning: Only selected Train Loading Groups were included in the results. Exclusion of results could lead to peak behaviours being missed and more critical conditions being excluded from the design process"

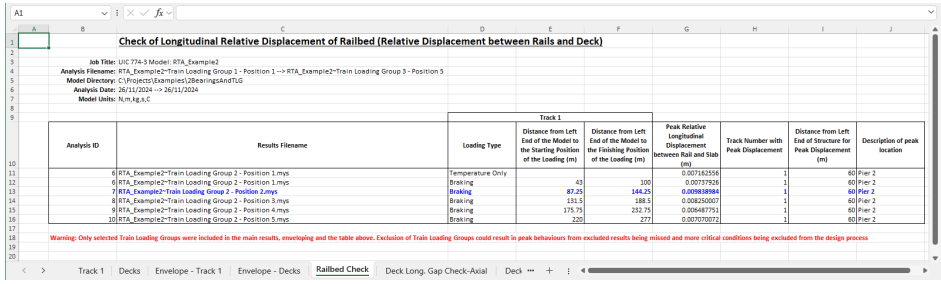
An identical warning is also placed at the top of the worksheet for the deck results and also at the top of the worksheets for the enveloped track and deck results.



The table of longitudinal relative displacement of the railbed that is created as part of the enveloping is shown in the following image. The restriction of the Train Loading Groups to just the second Train Loading Group is shown from the list of result filenames included (RTA_Example2~Train Loading Group 2 - Position 1.mys to RTA_Example2~Train Loading Group 2 - Position 6.mys). A warning message has also been added to the bottom of the table as follows due to the restricted post-processing of the track-structure interaction analysis:

"Warning: Only selected Train Loading Groups were included in the main results, enveloping and the table above. Exclusion of Train Loading Groups could result in peak behaviours from excluded results being missed and more critical conditions being excluded from the design process"

For these longitudinal relative displacement of the railbed results we have previously carried out a "whole model" post-processing, and we can therefore ignore this warning. Comparison of the railbed displacement result of +0.00984 m (+9.84 mm) from the post-processing of Train Loading Group 2 alone shows that this exactly matches the value of +0.00984 m (+9.84 mm) obtained when the whole model was post-processed, as expected.



Check of Longitudinal Relative Displacement of Railbed (Relative Displacement between Rails and Deck)

Job Title: UIC 774-3 Model: RTA_Example2
Analysis Filename: RTA_Example2~Train Loading Group 1 - Position 1 --> RTA_Example2~Train Loading Group 3 - Position 5
Model Directory: C:\Projects\Examples\2BearingsAndTLG
Analysis Date: 26/11/2024 --> 26/11/2024
Model Units: N,m,kg,s,C

		Track 1						
Analysis ID	Results Filename	Loading Type	Distance from Left End of the Model to the Starting Position of the Loading (m)	Distance from Left End of the Model to the Finishing Position of the Loading (m)	Peak Relative Longitudinal Displacement between Rail and Slab (m)	Track Number with Peak Displacement	Distance from Left End of Structure for Peak Displacement (m)	Description of peak location
6	RTA_Example2~Train Loading Group 2 - Position 1.mys	Temperature Only			0.007162556	1	60	Pier 2
6	RTA_Example2~Train Loading Group 2 - Position 1.mys	Braking	43	100	0.00737926	1	60	Pier 2
7	RTA_Example2~Train Loading Group 2 - Position 2.mys	Braking	87.25	144.25	0.009819984	1	60	Pier 2
8	RTA_Example2~Train Loading Group 2 - Position 3.mys	Braking	131.5	188.5	0.008250007	1	60	Pier 2
9	RTA_Example2~Train Loading Group 2 - Position 4.mys	Braking	175.75	232.75	0.006487751	1	60	Pier 2
10	RTA_Example2~Train Loading Group 2 - Position 5.mys	Braking	220	277	0.007070072	1	60	Pier 2

Warning: Only selected Train Loading Groups were included in the main results, enveloping and the table above. Exclusion of Train Loading Groups could result in peak behaviours from excluded results being missed and more critical conditions being excluded from the design process

Track 1 | Decks | Envelope - Track 1 | Envelope - Decks | Railbed Check | Deck Long. Gap Check-Axial | Deck

Inspection of the remaining worksheets of the post-processing will show similar warning messages and result comparisons. Choosing alternative forms of output restriction using the **Modify Included Output** dialog will allow different parts of the track-structure interaction analysis to be post-processed and will also lead to different warning messages being issued to the result spreadsheets.

Note. Ultimately it is the responsibility of the analyst to ensure that peak / most onerous behaviours are not missed when restricting the post-processing of a track-structure interaction analysis.

- Close the Microsoft Excel (or equivalent) application.

File
Close

- Choose **No** when asked to save the changes to the current model since there have been no manual changes to it and we want to preserve the original model built by the Rail Track Analysis software.

This completes the example.

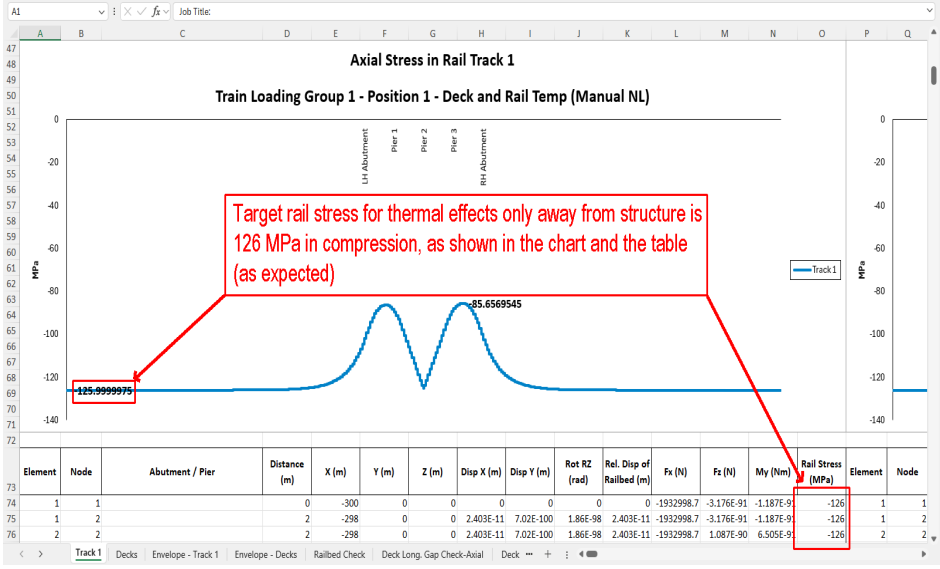
A brief discussion follows on the effect of the length of the approach embankments on the accuracy of the modelling.

Effect of Approach Embankment Length on Peak Axial Rail Stresses

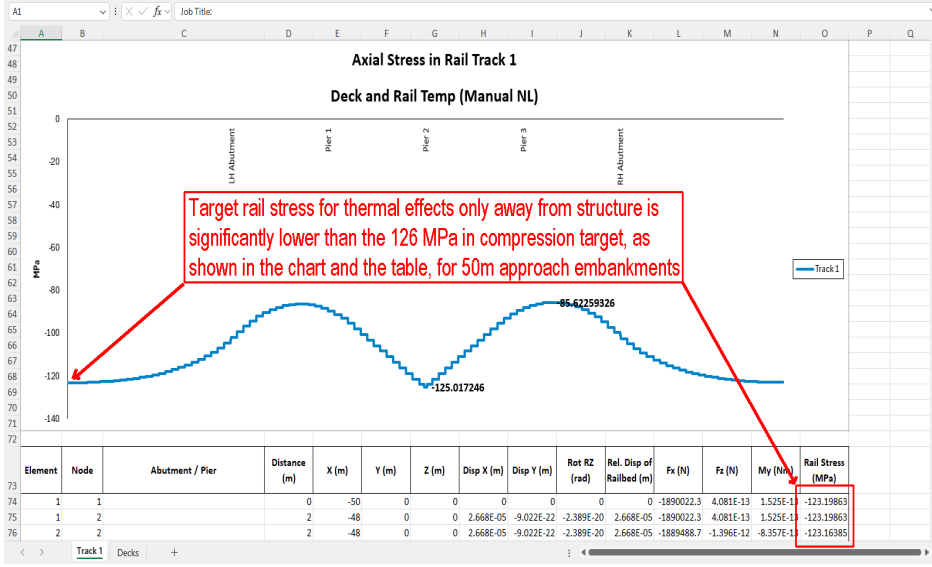
Within UIC774-3 it recommends that the minimum approach embankment length for modelling of track-structure interaction analyses is 100 m. This minimum has been used in this example and from inspection of the axial rail stresses at the extremes of the model the axial stresses are equal to -125.826749 MPa.

From the temperature behaviour of a restrained bar, it can be calculated that, with a coefficient of thermal expansion for the track of 1.2E-5, the target compressive stress in the track alone under thermal loading would be -126 MPa.

The axial stress achieved away from the structure is marginally lower than this target value but still within an acceptable tolerance of this target value. If, however, the approach embankments were extended to be 300 m the axial rail stresses at the extremes of the model become -125.9999975 MPa or -126 MPa which is exactly equal to the target of -126 MPa calculated above. This is shown in the image below.



The Railtrack Analysis Tool will allow approach embankments to be defined which are shorter than the 100 m recommended, but it is up to the user to establish whether these shorter approach embankments are sufficient for accurate modelling of the track-structure interaction analysis. Generally, the 100 m limit should be observed in accordance with UIC774-3 as indicated by the behaviour in the following image where the analysis has been performed with only a 50 m approach embankment. In this the axial rail stresses at the extremes of the model are only -123.19863 MPa which is not sufficiently close to the target of -126 MPa.



Element	Node	Abutment / Pier	Distance (m)	X (m)	Y (m)	Z (m)	Disp X (m)	Disp Y (m)	Rot RZ (rad)	Rel. Disp of Railbed (m)	Fx (N)	Fz (N)	My (Nm)	Rail Stress (MPa)
1	1		0	-50	0	0	0	0	0	0	-1890022.3	4.081E-13	1.525E-11	-123.19863
1	2		2	-48	0	0	2.668E-05	-9.022E-22	-2.389E-20	2.668E-05	-1890022.3	4.081E-13	1.525E-11	-123.19863
2	2		2	-48	0	0	2.668E-05	-9.022E-22	-2.389E-20	2.668E-05	-1889488.7	-1.396E-12	-8.357E-11	-123.16385