LUSAS

Rail Track Analysis User Manual

Rail Track Analysis User Manual

LUSAS Version 19.1 : Issue 1

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Rail Track Analysis

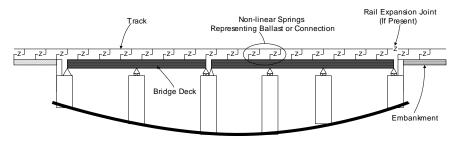
Introduction

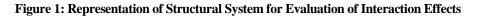
The passage of one or more trains crossing a rail bridge causes forces and moments to occur in the rails that, in turn, induce displacements in the supporting bridge deck, bearings and piers. As part of the design process for rail bridges it is necessary to ensure that any interaction between the track and the bridge as a result of temperature and train loading is within specified design limits.

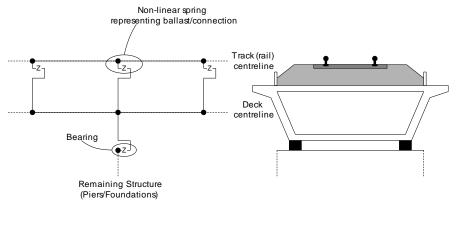
UIC774-3 Code of Practice

According to the Union Internationale des Chemins de fer (International Union of Railways) UIC774-3 Code of Practice, the track-structure interaction effects should be evaluated in terms of the longitudinal reactions at support locations, rail stresses induced by the temperature and train loading effects in addition to the absolute and relative displacements of the rails and deck. To accurately assess the behaviour these interaction effects should be evaluated through the use of a series of nonlinear analyses where all thermal and train loads are taken into account. These loads should be:

- □ Thermal loading on the bridge deck
- **D** Thermal loading on the rail if any rail expansion devices are fitted
- □ Vertical loads associated with the trainsets
- □ Longitudinal braking and/or acceleration loads associated with the trainsets







Longitudinal Schematic Of The Model

Transverse Cross-Section Of Track-Deck-Bearing System

Figure 2: Typical Model of Track-Deck-Bearing System

The interaction between the track and the bridge is approximated in the UIC774-3 Code of Practice by a bilinear relationship as indicated in the following figure. The resistance of the track to the longitudinal displacements for a particular track type is a function of both the relative displacement of the rail to the supporting structure and the loading applied to the track. If the track is subjected to no train loads then the ultimate resistance of the track to relative movement is governed by the lower curve in the figure (based on the track type). Application of train loads increases the resistance of the track to the relative displacements and the upper curve should be used for the interaction between the track and bridge where these train loads are present – unloaded resistance is still used for all other locations.

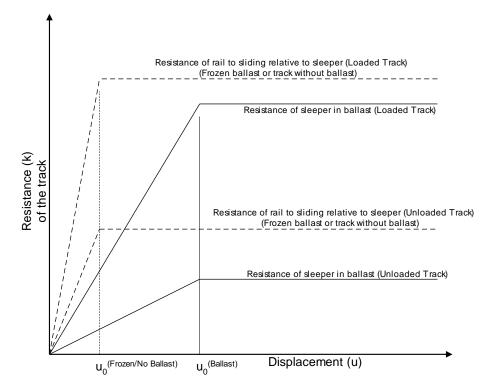


Figure 3: Resistance (k) of the Track per Unit Length versus Longitudinal Relative Displacement of Rails

The values of displacement and resistance to use in these bilinear curves are governed by the track structure and maintenance procedures adopted and will be specified in the design specifications for the structure. Typical values are listed in the Code of Practice for ballast, frozen ballast and track without ballast for moderate to good maintenance and are repeated below.

Displacement between the elastic and plastic zones, uo:

Resistance of the rail to sliding relative to sleeper = 0.5 mm

Resistance of sleeper in the ballast = 2.0 mm

Resistance in the plastic zone, k:

Resistance of sleeper in ballast (unloaded track), moderate maintenance = 12 kN/mResistance of sleeper in ballast (unloaded track), good maintenance = 20 kN/mResistance of loaded track or track with frozen ballast = 60 kN/mResistance of unloaded track for unballasted track = 40 kN/m

Resistance of loaded track for unballasted track = 60 kN/m

According to the UIC774-3 Code of Practice there is no requirement to consider a detailed model of the substructure (bearing-pier-foundation and bearing-abutment-foundation systems) when 'standard' bridges are considered, instead this can be modelled simply through constraints and/or spring supports that approximate the horizontal flexibility due to pier translational, bending and rotational movement. The LUSAS Rail Track Analysis option allows this type of analysis to be carried out where the behaviour of the bearing and the pier/abutment-foundation are individually specified but also provides the capability of explicitly modelling the bearing-pier/abutment-foundation systems where each component is defined, including the height and properties of the pier/abutment.

LUSAS Rail Track Analysis

The Rail Track Analysis option in LUSAS provides the means to automate the finite element analyses required for conducting bridge/track interaction analyses in accordance with the UIC774-3 Code of Practice. The key features are:

- □ LUSAS finite element models are automatically built from general arrangement, deck/abutment/pier properties, expansion joints, supports, interaction effects, and thermal and train loading data defined in a Microsoft Excel spreadsheet.
- □ Batch capabilities allow both multiple structures to be built and multiple rail load configurations to be analysed to investigate the interaction effects on different structures, the results of which can be enveloped to determine worst effects
- □ Rail and structure results are automatically extracted to Microsoft Excel for presentation and further processing

Worked Example

A worked example "Track-Structure Interaction to UIC774-3" is provided. This examines the track-structure interaction between a braking train and a single span bridge to replicate (as far as the original test data allows) testcase E1-3 which can be found in Appendix D.1 of the UIC774-3 Code of Practice.

The Rail Track Analysis Spreadsheet

A Microsoft Excel spreadsheet is used to define the data from which a LUSAS finite element model is built and a track/bridge interaction analysis carried out. The spreadsheet is separated into a number of worksheets that relate to particular aspects of the Rail Track Analysis input requirements. These worksheets cover:

- **I** Number of Decks, Tracks and Embankment Lengths
- □ Structure Definition
- **Geometric Properties**
- Material Properties
- □ Interaction and Expansion Joint Properties
- □ Loading

For each worksheet comments are included to advise on the appropriate input to the spreadsheet. These can be seen when hovering the mouse cursor over the cell of interest.

The template for the input spreadsheet is located in the \<**Lusas Installation** Folder>\Programs\Scripts\User folder. This template should be edited and saved under a different file name in the working folder in order to carry out analyses.



Note. All of the data entered into the Microsoft Excel spreadsheet should be in metric units. The required units are indicated in the various sections of the spreadsheet and should be adhered to for the correct modelling of the interaction analysis. When the model is built, all input will be converted to SI units of N, m, kg, C and s.

	A	В	C	D	E	F	G	Н	1	J	K	L	M
	Decks, Tracks and Embankment	Units : m	- U		La		0			0	IX.	6	191
	Decks, Hacks and Emparkment												
1	Number of Decks	1											
-	Number of Tracks	2											
	Left Embankment Length	100											
;	Right Embankment Length	100											
	Length of Decks Only / Total Length (m)	120	320	1									
	Length of Decks Only? Total Length (m)	120	520										
9 0													
1													
2													
2 3													
4													
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-	Decks, Tracks and Embankment Strue	ture Definition	🖉 Geometric	Properties _	🦯 Material Pr	operties					1000		•

Worksheet 1: Decks, Tracks and Embankment Lengths

Figure 4: Definition of Number of Decks, Tracks and Embankment Lengths

This worksheet defines the global arrangement details of the bridge structure. The inputs to the worksheet are:

Number of Decks

Defines the number of decks in the structure and controls the importing of the structure layout in the *Structure Definition* worksheet. The number of decks is initially limited to 100 but this number can be increased by modifying the *Structure Definition* worksheet as outlined in the following section.

Number of Tracks

Defines the number of railway tracks that pass along the structure and embankments. The number of tracks can be set as either one or two. For two tracks, one track should take the braking load of a trainset and the other the acceleration load of a separate trainset in accordance with the UIC77-3 Code of Practice (Clause 1.4.3). Each track consists of two rails which act together (see the *Geometric Properties* section).

Left and Right Embankment Length

Defines the lengths of the left and right embankments in the model illustrated in the figure below. These lengths should be sufficiently long to allow the trainset loading to be placed in the model and, according to the UIC774-3 Code of Practice, should be greater than 100m (Clause 1.7.3).



Figure 5: Left and Right Embankments in Model

Worksheet 2: Structure Definition

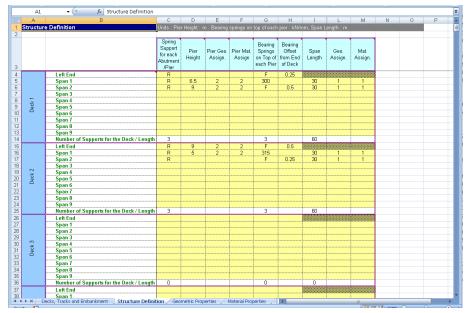


Figure 6: Structure Definition

The *Structure Definition* worksheet allows the geometry of the bridge to be input deck by deck. For each deck the worksheet allows the definition of the length, geometric and material assignments of the internal spans plus pier/abutment arrangements along with their support and bearing characteristic. The input allows the modelling of the piers through equivalent springs using the method proposed in the UIC774-3 Code of Practice (see note below) or through the physical modelling of the piers by entering input of the pier heights plus geometric and material assignments. The inputs to the worksheet are:

Spring Support for each abutment/pier

Defines the longitudinal stiffness for the abutment or pier. The longitudinal stiffness for the abutment or pier should be entered as either free 'F', restrained 'R' or a positive stiffness in kN/mm.

For the equivalent spring approach, if the displacement behaviour of the support and the bearings are modelled separately the supports should be set to take account of the displacement at the top of the support due to elastic deformation, the displacement at the top of the support due to the rotation of the foundation and the displacement at the top of the support due to the longitudinal movement of the foundation. If instead the displacement behaviour of the support and bearings are lumped together, as illustrated in the example in Figure 6, the spring supports for the piers and abutments should be set to 'R' for restrained.

If the piers are physically modelled then the spring support for the pier should represent the longitudinal stiffness of the foundation at the base of the pier.



Note. The pier properties for the last pier of one deck must exactly match the properties defined for the next deck or an error will be reported when the Microsoft Excel spreadsheet is used to carry out the analysis.



Note. When the pier/foundation system is modelled as a spring this spring can be calculated by combining the component movements associated with the pier as indicated below and described further in the UIC774-3 Code of Practice:

$$\delta_{\text{total}} = \delta_{\text{p}} + \delta_{\varphi} + \delta_{\text{h}} + \delta_{\text{b}}$$

where

 δ_p = displacement at top of support due to elastic deformation

 δ_{ϕ} = displacement at top of support due to rotation of the foundation

 δ_h = displacement at top of support due to horizontal movement of the foundation

 δ_b = relative displacement between the upper and lower parts of bearing (Only included if bearings effects lumped into support conditions)

and the total spring stiffness is calculated from:

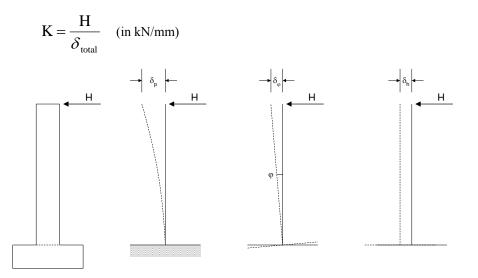


Figure 7: Component Behaviour for Calculating Support Stiffness



Note. If the piers are modelled in the analysis the rotation of the foundation is assumed to be zero in the analysis. This can be adjusted by modifying the support conditions manually after a temperature only analysis has been performed (see user interface discussions)

Bearing springs on top of each pier

Defines the longitudinal stiffness of the bearings between the top of the support and the deck. The longitudinal stiffness for the bearing should be entered as either free 'F', restrained 'R' or a positive stiffness in kN/mm.

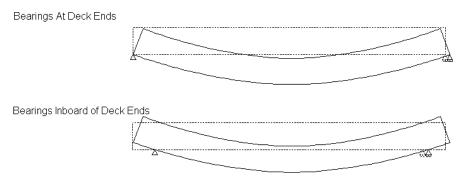
For the equivalent spring approach where the stiffness of the support due to elastic deformation, rotation of the foundation and horizontal movement of the foundation are lumped with the bearing behaviour this input should include all of the stiffness contributions and the *Spring support for each abutment/pier* should be set to 'R'. If the bearing behaviour is separated from the behaviour of the support the input should match the requirements for the bearing alone.

When the piers are physically modelled in the model by setting their height and properties the longitudinal stiffness of the bearing alone should be input since the behaviour of the pier will be incorporated by the extra beam elements representing the pier in the model.

Bearing offset from end of deck

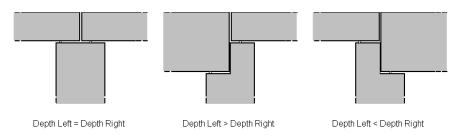
Defines the offset from the end of the deck for the longitudinal location of the bearing. The bearing offset should be in m.

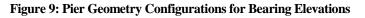
The bearing at the end of the deck may not be at the end (or sufficiently close to the end) of the deck to be able to justify such modelling as contained in UIC774-3 where bearings are assumed to be at the end. If the bearing is inboard of the end of the deck this can have a significant effect on the displacement / bending behaviour of the deck which itself can have an effect on the track-structure interaction and the displacement behaviour between decks plus the deck ends and the abutments as illustrated below.





When bearing offsets are used with physical pier modelling the physical geometry of the pier will be built with rigid offsets modelled to ensure the bearing bases are at both the correct longitudinal location relative to the pier and also at the correct elevation as shown in the image below. This modelling ensures the correct translational and rotational behaviours of the bases of the bearing for the displacement and rotation of the supporting pier.





This additional displacement from the correct longitudinal bearing offset modelling could increase the observed displacements of the decks themselves and could be more detrimental to the track-structure interaction.

Bearing offsets can be used when the equivalent spring pier modelling is being used but there is no ability to incorporate the additional rotation of the top of the pier and its effect on the bases of the bearings since the rotation behaviour of the pier is accounted for solely in the longitudinal stiffness used in the equivalent spring pier modelling and not through a degree of freedom in the analysis. It is therefore recommended that bearing offsets are **not** used when equivalent spring pier modelling in accordance with UIC774-3 is being used.

Span Length

Defines the span length between support locations for a deck. Up to nine spans can be defined for each deck. In the example illustrated in Figure 6 the first two decks have two 25m spans each and the third deck has three 25m spans.

Geometric Assignment

Defines the geometric properties that are assigned to the spans of the decks. The integer ID <u>must</u> match one of the geometric properties that is defined in the *Geometric Properties* worksheet. Different properties can be assigned to each span of the deck. Although the input only allows a single ID to be assigned to each span, continuously varying properties can also be modelled (see the section on *Geometric Properties*).

Material Assignment

Defines the material properties that are assigned to the spans of the decks. The integer ID <u>must</u> match one of the material properties that is defined in the *Material Properties* worksheet.

If physical modelling of the piers is to be included in the analysis then additional input is required for these piers. The inputs to the worksheet are:

Pier Height

Defines the height of the support / pier for the current location in the deck. If the pier height is blank the wizard assumes that the pier behaviour is represented solely by the spring supports and bearing springs.

Pier Geometric Assignment

Defines the geometric properties that are assigned to the support / pier for the current location in the deck. The integer ID <u>must</u> match one of the geometric properties that is defined in the *Geometric Properties* worksheet. Although the input only allows a single ID to be assigned to the support / pier, continuously varying properties can also be modelled (see the section on *Geometric Properties*).

Pier Material Assignment

Defines the material properties that are assigned to the support / pier for the current location in the deck. The integer ID <u>must</u> match one of the material properties that is defined in the *Material Properties* worksheet.

Increasing the number of decks modelled

If more than 100 decks are required the Microsoft Excel spreadsheet can be modified. To do this, scroll to the end of the *Structure Definition* worksheet and select the last complete deck definition as indicated on the figure below.

	A1093	 ✓ f_x ="Deck "&J1103 												
- 4	A	В	C	D	E	F	G	Н	1	L	M	N	0	P
	Structure	Definition	Units : Pie	r Height : r		springs on	top of each			ength : m				
2														
			Spring				Bearing	Bearing						
			Support	Pier	Pier Geo.	Pier Mat.	Springs	Offset	Span	Geo.	Mat.			
			for each	Height	Assign.	Assign	on Top of	from End		Assign.	Assign.			
3			Abutment /Pier				each Pier	of Deck						
089		Span 7	7Fier											
090		Span 8												
091		Span 9												
092		Number of Supports for the Deck / Length	0				0		0					
093	11111	Left End												
094		Span 1												
095		Span 2												
096	Ē	Span 3												
097	5	Span 4												
098 099	Deck .	Span 5 Span 6												
100	-	Span 7												
101		Span 8												
102		Span 9												
103		Number of Supports for the Deck / Length	0				0		0					
104												,		
105														
106														
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		ks, Tracks and Embankment Structure Definiti	· · · · · · · · · · · · · · · · · · ·			laterial Prope								

Figure 10: Selection and Copying of Structure Definition Worksheet to Increase Number of Decks

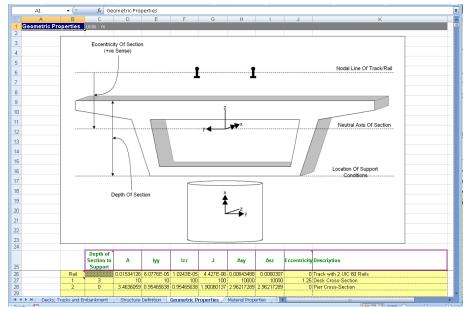
Copy and paste this section as many times as required at the end of the worksheet, ensuring that the row formatting is not altered as indicated below. If successful, the deck number should be correctly calculated for the added entries. The number of decks in the first worksheet of the spreadsheet can now be increased to the number of decks added to the structure definition.



Note. This may require the worksheet to be unprotected first which can be done under the Review options in Microsoft Excel. This worksheet protection should be turned back on immediately after the extra entries for additional decks have been inserted into the worksheet to avoid accidental changes to other parts of the worksheet that could cause errors when the spreadsheet is imported into the Rail Track Analysis tool.

-	A1104	• 🖉 🏂 ="Deck "&J1114													-
4	A	В	С	D	E	F	G	Н		L	M	N	0	P	-
. F	Structure	Definition	Units : Pie	r Height : i	m : Bearing	springs on	top of each	i pier : kIVr	nm, Span L	.ength : m	_		_		
			Spring		1		Bearing	Bearing							
			Support	Pier	Pier Geo.	Pier Mat	Springs	Offset	Span	Geo.	Mat.				
			for each	Height	Assign.	Assign		from End	Length	Assign.	Assian.				
			Abutment	rioigin	i weign:		each Pier	of Deck	eeng.		r iooigin				
			/Pier												
9		Span 7													
10		Span 8					ļ		ļ		ļ				
91		Span 9													
92		Number of Supports for the Deck / Length	0				0		0						
33		Left End													
94		Span 1													
95		Span 2													
6	8	Span 3													
97	-	Span 4													
8	Deck 100	Span 5													
9	-	Span 6													
00		Span 7					ļ				ļ				
01		Span 8						ļ							
12		Span 9													
13		Number of Supports for the Deck / Length	0		+		0		0		haaaaaaa				
14		Left End								ļ					
95		Span 1													
96		Span 2													
07	Deck 101	Span 3													
18	-	Span 4													
19	e e	Span 5													
0	-	Span 6													
1		Span 7													
2		Span 8 Span 9													
4			0				0		0						
5		Number of Supports for the Deck / Length	0				0		0						
6												re.			
7															
8															
9															
30															
2U 21															
21 22															
23															
	N Dec	ks. Tracks and Embankment Structure Definit		antain Danas	anting Ad	aterial Prop	erties / ii	4		1			1		-

Figure 11: Pasting of Additional Decks to Ensure Formatting Maintained



Worksheet 3: Geometric Properties

Figure 12: Geometric Properties Table for Structure

The geometric properties worksheet should list all of the section properties required for the modelling of the structure and the unique ID numbers <u>must</u> include all of the geometric properties that have been assigned in the *Structure Definition* worksheet. The properties should be entered in metres and are all standard LUSAS values except the *Depth of Section to Support* entry that is needed by the model building to ensure the support conditions occur at the correct elevation.

Element Orientations

The orientations of the sectional properties should obey the axes indicated in the illustration within the worksheet and the element local axes indicated in the following figure where the double-headed arrow indicates the element local x-axis, the single headed arrow indicates the element local y-axis and the line without an arrowhead indicates the element local z-axis. For both the spans and the piers the element local y-axis orientated vertically for the spans and in the longitudinal direction for the piers.

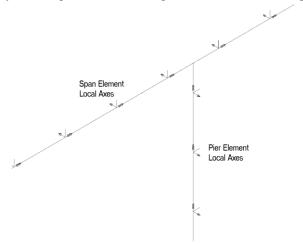
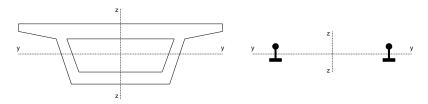


Figure 13: Beam Element Local Axes for Deck and Pier Modelling

For defining the geometric properties of the decks and rails the section axes are illustrated in Figure 14.





When the tracks are modelled the two rails of a track are assumed to behave together and the section properties should therefore take account of both rails. When analysing a single track structure it is possible to approximate the behaviour of individual rails by choosing to model two tracks and only defining the section properties for a single rail in the *Geometric Properties* worksheet. Caution should be used when considering modelling of this type as the analysis will ignore any connectivity between the two rails that may be provided by the sleeper arrangement.

Eccentricity

All eccentricity in the modelling is defined relative to the nodal line of the track/rail and therefore a positive eccentricity will place a section below this line as indicated in the following figure. If an eccentricity is entered for the geometric property of the rail then the neutral axis of the rail will be offset from this nodal line based on the positive sense described. For this reason the eccentricity of the rail should generally be set to zero for all cases.



Notes

The number of entries can be increased by adding data to the bottom of the table. Data input will terminate on the first blank ID number in column B.

The depth of section should not be defined for geometric properties assigned to piers.

The eccentricity between the rail/slab indicated in the figure is defined later in the interaction worksheet and should not be defined as a geometric property.

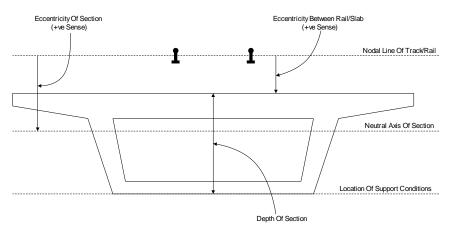


Figure 15: Eccentricity Definition for Geometric Properties and Depth of Section

Varying Section Geometric Properties

Although the Microsoft Excel spreadsheet does not allow the input of geometric properties with varying sections it is possible to analyse structures with varying sections by modifying the temperature loading only model after it has been built by the wizard before subsequently using the **Apply Rail Loads** dialog to include the trainset

loading. To do this the model should be defined in the spreadsheet with an initial set of deck geometric properties.

All sections that will be used to define the varying sections of the deck must be defined externally in separate models using either the Precast Beam Section Generator, the Box Section Property Calculator or the Arbitrary Section Property Calculator and the sections added to either a local library or the server library. This will make these sections available to other models.



Note. The *Depth of Section* must be correctly set in the *Geometric Properties* worksheet for each of the deck support locations to ensure that the behaviour of the decks is correct. All other entries will be determined from the varying section.

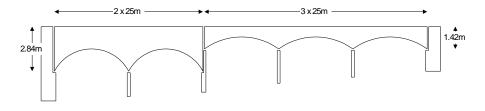


Figure 16: Example Varying Section Structure

If the structure in Figure 16 was required, the main track-structure interaction model could be set up using a Microsoft Excel Spreadsheet with the *Structure Definition* and *Geometric Properties* indicated in Figure 17 and Figure 18. This would define the base model indicated in Figure 19.

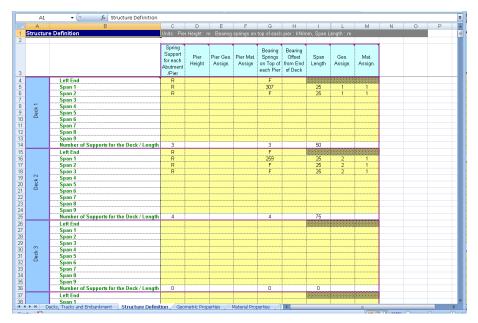


Figure 17: Structure Definition for Sample Varying Section Structure

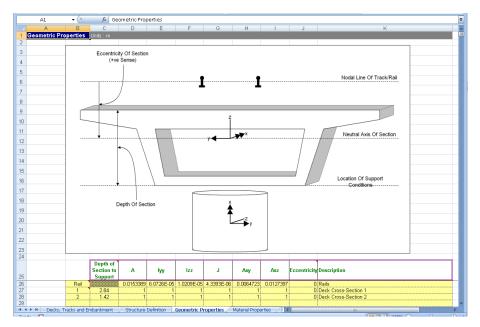


Figure 18: Geometric Properties for Sample Varying Section Structure



Figure 19: Base Model for Sample Varying Section Structure

In order to define the smooth variation for a single span of the decks the minimum number of sections for interpolation is five. For the 2.84m and 1.42m deep deck spans these sections are defined in separate models, calculated with the *Arbitrary Section Property Calculator* (as illustrated in the figure below for one of the sections from the 2.84m deep deck spans) and then added to the local library so they can be accessed from other models (NOTE: Only three actual sizes need to be defined for each due to symmetry).

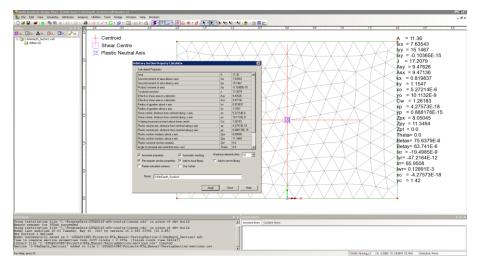


Figure 20: Arbitrary Section Property Calculation for 2.84m Depth of Section Span

These sections can now be used to define the *Multiple Varying Section* facility in Modeller. Before defining these multiple varying sections the reference paths along which the variation will take place must be defined. Define a reference path for each of the spans as illustrated in Figure 21 for the first span of the first deck. In this definition the X coordinates match the extent of the span and the Y coordinate has been set to 10 so it can be visualised easily. Four additional reference paths should also be defined, one for each of the other spans. On completion the model will resemble the one in Figure 22 where each reference path has been offset in the Y direction for visualisation purposes.

Туре		(m) Z (r	0.5
1 Start 2 Straight	0 1 25 1		0.3
2 Straight	23 1		7
			-0.1
			-0.5
			0 5 10 15 20
			XY XX XX XX
			10.5
			10.3
			Y 10.1
	In	sert Delei	9.9
			9.7
Smoothing Minimum radius	Cut corner 🔔		9.5 0 5 10 15 20
0.0	O Offset line		
1	C Officente		Reverse Flip
Transverse direction —			
Perpendicular to p		ĥ	Value of distance at start of path:
🔿 Skew angle	0.0 °		• 0.0 m
C Local coordinate	2:Offset/Pier Lo	cal Coordinate	
Name Path	- Deck 1, Span 1		• (new)
			+ (1011)

Figure 21: Definition of Reference Path for Deck 1, Span 1



Figure 22: Reference Path for all Decks and Spans (Offset for Visualisation Purposes)

The varying sections can now be defined using the *Multiple Varying Section* dialog. For the definition of the varying section for the first span of the first deck the distance interpretation should be set to *Along reference path* and the path for the first span of the first deck selected ("Path – Deck 1, Span 1" in this example – see Figure 21). For the start of the varying section the 2.84m deep section ("2-84mDepth_Section1" in this case) should be selected from the user library and the section edited. The eccentricity in the z direction (ez) <u>should be set to the required value of 1.42m</u> to obtain the required eccentricity of the neutral axis of the section from the nodal line of the track / rail which would have been entered into the *Geometric Properties* worksheet. At this stage the Multiple Varying Section dialog will just have the starting section as illustrated in Figure 23.

nalysis category 3D 5 Specify shape interpolation 5 Symmetric section	C Scaled to fit each I	C Scaled to fit each line individually C Along reference path Path - Deck 1, Span 1							
Section	Shape Interpolation	Distance	Edit						
2-84mDepth_Section1	Start	0.0	Delete						
			Flip						
Alignment Vertical Top to top Horizontal Centre to centre	Align all sections to s Y Interpolation of prop		T						
	A3 A2 y A4 A1		100%						
Name Deck 1 - Span 1		T	▲ (new)						

Figure 23: Definition of Multiple Varying Section for Deck 1, Span 1 (1 of 2)

The other sections defining the span also need to be added to the varying section definition and these are input as follows with the *Vertical alignment* set to *Centre to centre* and the *Horizontal alignment* set to *Right to right*:

Section	Shape Interpolation	Distance
2-84mDepth_Section2	Smoothed	5.0
2-84mDepth_Section3	Smoothed	12.5
2-84mDepth_Section2	Smoothed	20.0
2-84mDepth_Section1	Smoothed	25.0

Analysis cateo Specify sh	ape interpolation	Distance interpretation Scaled to fit each line individually Along reference path Path - Deck 1, Span 1							
	Section	Shape Interpolation	Distance	Edit					
	th_Section1	Start	0.0	Insert					
	th_Section2 th_Section3	Smoothed Smoothed	5.0 12.5	Delete					
	th_Section2	Smoothed	20.0	Flip					
5 2-84mDep		Smoothed	25.0 🔹						
Alignment — Vertical Horizontal	Centre to centre Right to right	Align all sections to Interpolation of pro	section 1 -	-					
1	2	3	4	100% 5					
i Sec	2 tion 1-1 Section	3 n 2-2 Section 3-3 Sec	4 tion 4-4 Section	5 15-5					
Nan	ne Deck 1 - Span 1		•	(new)					

Figure 24: Definition of Multiple Varying Section for Deck 1, Span 1 (2 of 2)

This multiple varying section can now be assigned to all of the lines defining the first span of the first deck, overwriting the original assignment from the wizard. A similar multiple varying section can also be defined and assigned but using the appropriate reference path for the second span of the first deck.

The same procedure should also be followed for the 1.42m deep section using associated sections and a starting eccentricity in the z direction (ez) of 0.71m to obtain the required eccentricity of the neutral axis of the section from the nodal line of the track / rail which would have been entered into the *Geometric Properties* worksheet. On completion and assignment of the multiple varying section geometric attributes to the appropriate spans of the model the structure would look similar to the model in Figure 25.

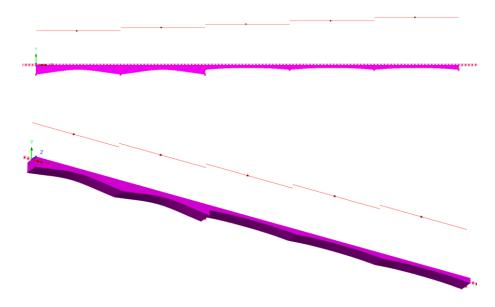


Figure 25: Model after Assignment of Multiple Varying Sections



Note. The multiple varying section could be defined with just two reference paths, one for each of the decks and the geometric attributes defined as indicated in Figure 26. When modelling structures where the sections do not vary smoothly, for example over a pier as indicated in Figure 16, caution should be exercised as using a single reference path per deck could lead to artificial smoothing of the section variation. This is illustrated in Figure 27 and Figure 28 which examine the behaviour at an intermediate pier of a deck when a single path is used for each deck. In Figure 28 the image on the left is from the use of a single reference path for the whole deck and shows the smoothing that has occurred over the pier when compared to the image on the right which is from the use of a single reference path for each span of the deck.

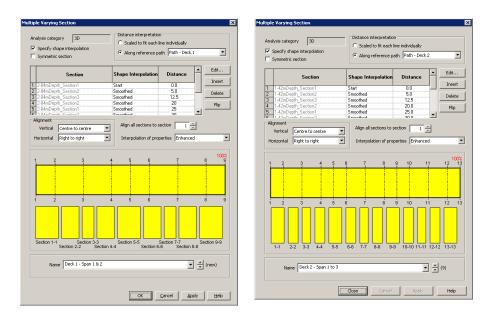


Figure 26: Definition of Multiple Varying Section for Deck 1 and Deck 2 for Two Reference Paths



Figure 27: Model after Assignment of Multiple Varying Sections with Two Reference Paths

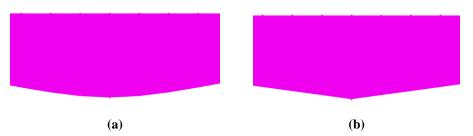
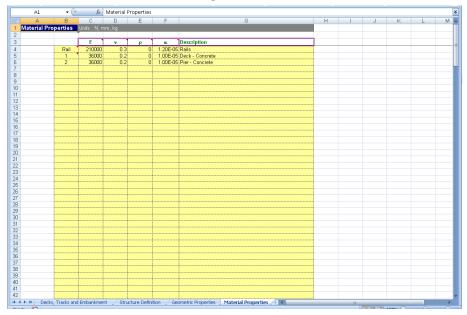


Figure 28: Zoomed Plot of Pier Location between Spans of Deck 1 Showing (a) Smoothed Section for a Multiple Varying Sections with One Reference Path per Deck and (b) Correct Unsmoothed Section for a Multiple Varying Sections with One Reference Path per Span



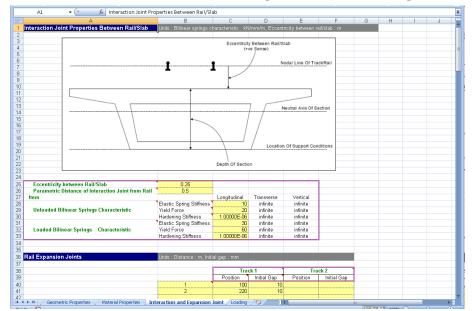
Worksheet 4: Material Properties

Figure 29: Material Properties Table for Structure

The material properties worksheet should list all of the material properties required for the modelling of the structure and the unique ID numbers <u>must</u> include all of the material properties that have been assigned in the *Structure Definition* worksheet. The elastic properties are all standard LUSAS values which should be entered in Newtons, millimetres and kilograms. The mass density (ρ) is not used in the analysis but is provided to allow the model to be solved with self-weight loading and for it to be combined with the thermal/train loading effects covered in these analyses.



Note. The number of entries can be increased by adding data to the bottom of the table. Data input will terminate on the first blank ID number in column B.



Worksheet 5: Interaction and Expansion Joint Properties

Figure 30: Interaction Properties Between the Track/Bridge and Expansion Joint Definition

The main bilinear interaction effects for the track/bridge interaction are defined in this worksheet along with additional properties associated with the rail/track. These include the eccentricity between the rail/slab (see Figure 11 and the *Geometric Properties* section) and the presence of any rail expansion joints.

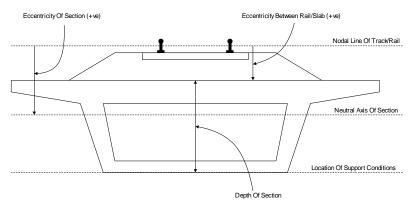
Eccentricity Between Rail/Slab

The eccentricity between the rail/slab is used to define the distance between the nodal line of the rail/track and the top of the bridge slab/deck as indicated in Figure 11. In general, all eccentricities will be positive in the modelling unless the neutral axis of the structure section is above the level of the rails. This only happens for certain types of structures and the definitions of eccentricity should generally follow the sign conventions defined in the following figure.

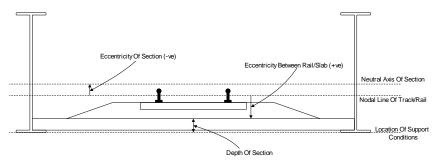
Parametric Distance of Interaction Joint from Rail

The position of the interaction joint from the rail is controlled by this entry. When the eccentricity between the rail/track and the top of the bridge slab/deck is small the eccentricity can be modelled using eccentricity in the elements representing the components of the model. For larger eccentricities the positioning of the rail/track relative to the bridge slab/deck should be modelled using rigid offsets and the positioning of the interaction joints can be set to be at the elevation of the rail/track by

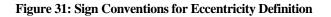
setting this entry to 0, at the elevation of the bridge slab/deck by setting this entry to 1, or at any position in between by setting a value between 0 and 1. If the entry is undefined the Rail Track Analysis tool will assume a value of 0.5 to place the interaction joints midway between the rail/track and the bridge slab/deck.



Eccentricity Definitions (Section Neutral Axis Below Rail Level, Support At Base)



Eccentricity Definitions (Section Neutral Axis Above Rail Level, Support At Base)



Bilinear Interaction Properties

The bilinear interaction properties are derived from the bilinear curves defined in the UIC774-3 Code of Practice. Properties are entered for both the unloaded state where just temperature loads are applied in the model to the track and the loaded state where both temperature and trainset loads are applied to the track. For each state of loading the elastic spring stiffness is defined in kN/mm per metre length of track, the yield force (onset of plastic yield) is defined in kN per metre length and the hardening stiffness defined as a small value so there is no stiffness once plastic yielding has started. The values in Figure 30 are for unballasted track where the displacement

between the elastic and plastic zones and the associated resistance in the plastic zone are (see the earlier discussion on the bilinear relationship):

$$u_0 = 0.5mm$$

$$k = 40kN / m (Unloaded)$$

$$k = 60kN / m (Loaded)$$

The elastic spring stiffness is calculated directly from:

Contact Stiffness =
$$\frac{k}{u_0}$$

giving 80 kN/mm/m for the unloaded and 120 kN/mm/m for the loaded interaction elastic spring stiffness values. The transverse spring properties of the interaction should always be infinite (as the analysis is two-dimensional even though the elements are three-dimensional) but the vertical spring properties can be adjusted from this to include vertical deformation effects of the ballast by building the temperature only model and editing the model before applying the trainset rail loads. If this type of analysis is carried out, care must be taken to ensure that the spring remains in the elastic regime. This is achieved by setting a very high value for yield force (1.0E12 kN/mm per metre length for example) and ensuring that the hardening stiffness is set to the same stiffness value as the elastic spring stiffness.



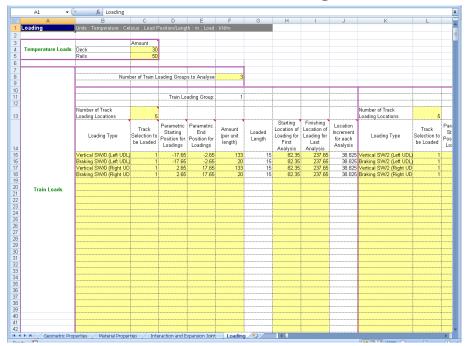
Note. If a zero or small yield force is used in the interaction characteristics the default settings for the nonlinear convergence scheme used in the solution may not result in a converged solution. These convergence parameters my need to be adjusted and the model resolved if this occurs.

Defining Rail Expansion Joints

If rail expansion joints are present in the bridge then the information for these can be entered into the worksheet for each track. The data input takes the form of a unique positive ID number that is placed in column B, the positions and initial gaps. The expansion joint data will be read from the spreadsheet until a blank ID entry is detected. For each unique ID number an expansion joint can be defined for either track by entering the position in metres from the start of the left-hand embankment and initial gap in millimetres.

A1 🔹 🏂 Interaction Joint Pro	operties Between Rail/SI	ab					
A	В	C	D	E	F	G H	J
1 Interaction Joint Properties Between Rail/Slab	Units : Bilinear springs c			ricity between r			
2	-						
3		Eccentricit	/ Between Rail/S	lab			
4			e Sense)				
5			/				
6	•	•	/ N	odal Line Of Tra	ick/Rail		
7							
8		-					
9		-					
10	+	+					
11 12							
12			7				
14			//	leutral Axis Of S	ection		
15	-	/	/				
16		. /	/				
17			/				
18			/				
19			/ Location	Of Support Cor	ditions		
20			4				
21		1					
22		Depth Of Section	n				
23							
24					1		
25 Eccentricity between Rail/Slab	0.5						
26 Parametric Distance of Interaction Joint from Rail	0.5		-				
27 Item 28	Elastic Spring Stiffness	Longitudinal 80	Transverse infinite	Vertical infinite			
29 Unloaded Bilinear Springs Characteristic	Yield Force	80 40	infinite	infinite			
30	Hardening Stiffness	40 1.00000E-06	infinite	infinite			
31	Elastic Spring Stiffness	120	infinite	infinite			
32 Loaded Bilinear Springs Characteristic	Yield Force	60	infinite	infinite			
33	Hardening Stiffness	1.00000E-06	infinite	infinite			
34					8		
35							
36 Rail Expansion Joints	Units : Distance : m, Init	ial gap : mm					
37							
38		Tra	:k 1	Tra	ick 2	1	
39		Position	Initial Gap	Position	Initial Gap		
40	1	300	5				
41	2	475	5	475			
42	3			625	5		
HIGHT Geometric Properties / Material Properties In	teraction and Expansion	loint Loading	/ ?] /	1			• 1

Figure 32: Sample Expansion Joint Definitions



Worksheet 6: Thermal and Train Loading

Figure 33: Definition of Thermal and Train Loading for Structure

The loading worksheet allows the input of the temperature and trainset loading characteristics that are to be considered for the structure. This includes the capability of defining multiple trainset configurations and locations using the Train Loading Groups and parametric loading facilities which are described below.

Temperature Loading

The temperature effects in the rails for a continuously welded rail (CWR) track do not cause a displacement of the track and do not need to be considered (UIC774-3 Clause 1.4.2). For all other tracks the change in temperature of the bridge deck and rails relative to the reference temperature of the deck when the rail was fixed needs to be considered in accordance to the code of practice and design specifications. The temperature loads for both the slab/deck and the rail should be entered (zero if not required) in Celsius (degrees centigrade) where temperature rises are entered as positive values and temperature drops are entered as negative values.



Note. For structures where more than one temperature loading may need to be entered for the deck (e.g. mixed steel and concrete bridges) the model should be defined with a single deck temperature and then a temperature only model built. This model can then have its temperature loading for the deck adjusted before the **Apply Rail Loads** dialog is then used to include the trainset loading to the railtracks.

Trainset Loading to Rails of Tracks

The Rail Track Analysis tool allows the analysis of the positioning / movement of multiple trainset configurations within the same overall Rail Track Analysis. This is done through the Train Loading Groups and parametric positioning of the trainsets within each of these. This can be used for either the global passage of multiple different trainset configurations across the whole structure (such as an analysis containing SW/0, SW/2 and HSLM-A trainset configurations / loadings to assess the overall behaviour to each of these) or the targeted and / or more detailed placement of a single (or more) trainset configurations at critical positions indicated by a prior global analysis or by engineering judgement.

For each of the Train Loading Groups the trainset loading is defined in terms of the type, track to load, position and magnitude. The loading allows for multiple trainset loading positions to be defined in each Train Loading Group and all of these positions will be analysed in one model by the wizard.

Since trainset configurations can be longer than the approach embankment recommendations of UIC774-3 (and in some cases could be significantly longer than the approach embankment and structure) the Rail Track Analysis tool allows the trainset loading to fall outside the extents of the model.

Currently the **Loading** worksheet of the input Microsoft Excel spreadsheet allows up to 10 Train Loading Groups (each with 125 rows of loading definitions to describe the longitudinal and vertical loading pattern) to be defined within the formatting.

As many rail/train loads that are required can be defined in the spreadsheet with data input terminating when blank data is detected in the loading type column. This allows more complex loading patterns to be defined such as those illustrated in Figure 34 and "Appendix B: Definition of Complex Trainset Configurations". To extend the bottom of the table extra rows can be inserted (making sure to copy the formulae in columns G and J for Train Loading Group 1 and similarly for others) or the last rows copied and pasted as many times as required.

Similarly, should the number of Train Loading Groups need to be increased from the 10 provided in the template this can be done by selecting the whole of the region defining the tenth Train Loading Group (as indicated in Figure 35) and pasting it as many times to the right of the existing Train Loading Groups (as indicated in Figure 36).



Note. This may require the worksheet to be unprotected first which can be done under the Review options in Microsoft Excel. This worksheet protection should be turned back on immediately after the extra entries for additional loads have been inserted into the worksheet to avoid accidental changes to other parts of the worksheet that could cause errors when the spreadsheet is imported into the Rail Track Analysis tool. The inputs to the worksheet are:

Number of train loading groups to analyse

Defines the number of Train Loading Groups to include in the analysis. If only a single trainset configuration is to be considered then this should be set to 1. To analyse more than 1 Train Loading Group the number should be set to a positive integer equal to (or less than) the number of Train Loading Groups that have been defined in the worksheet. No breaks / gaps are permitted in the definition of the Train Loading Groups.

Then, for each of the Train Loading Groups the inputs are:

Number of track loading locations

Defines the number of parametric locations for the placement of the trainset loading carried out in the analysis of this Train Loading Group. If only a single position of the trainset loading is to be considered then this should be set to 1. To analyse more than 1 location the number should be set to a positive integer.

Loading type

Defines the loading type that will be assigned to the selected track. The first character governs the loading type with valid options being Acceleration, Braking, Traction and Vertical. A more descriptive definition of the loading type may be entered if required as illustrated in "Appendix B: Definition of Complex Trainset Configurations" so long as the first character is set to either A, B, T or V.

Track selection to be loaded

Defines the track that the loading will be assigned to for the current Train Loading Group and can be either 1 or 2 (only if the structure is a two track structure). For two tracks the UIC774-3 Code of Practice (Clause 1.4.3) states that the accelerating and braking forces from trainsets should be applied to different tracks.

Parametric starting position for loadings

Defines the starting parametric position of the loading of the trainset for the current Train Loading Group. For the trainset the starting position is the left-most position of the load when considering the trainset alone (i.e. independent of the structure). The reference parametric position used for the combination of the trainset loading and the current position on the structure is at a value of zero so positions that are negative will place the defined loading to the left of the reference position defined using the entries in columns H and I and positions that are positive will place the loading to the right.

Parametric end position for loadings

Defines the ending parametric position of the loading of the trainset for the current Train Loading Group. For the trainset the ending position is the right-most position of the load when considering the trainset alone (i.e. independent of the structure). These are relative to the reference position as described for the parametric starting position above.

Amount (per unit length)

Defines the magnitude of the trainset loading in units of kN per metre length for the current Train Loading Group. For longitudinal loads such as acceleration, traction and braking loads a positive value will cause the loading to act towards the right embankment, a negative value will cause the loading to act towards the left embankment. For vertical loads a positive value will cause the loading to act downwards onto the track and structure.

Loaded length

The loaded length is automatically calculated from the parametric starting and end position for the loading and provides a check that these values have been entered correctly. Negative or zero loaded lengths are not permitted in the modelling.

Figure 34 illustrates some trainset loading configurations and their input into the worksheet. Examples (d) and (e) in this figure are equivalent and both definition methods are equally valid in the worksheet. Further examples are illustrated in "Appendix B: Definition of Complex Trainset Configurations".

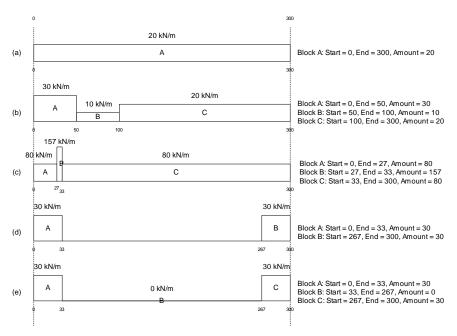


Figure 34: Sample Trainset Loading Position Definitions



Note. It is possible to approximate concentrated loads in trainset loading configurations through the use of UDLs over small contact lengths. Due to the scale of the modelling, with elements typically 1 to 2m in length, the use of a small contact length (such as 5 to 10% of the element length or smaller) allows the concentrated load to be modelled. The procedure for modelling concentrated loads within the Rail Track Analysis tool is covered in "Appendix B: Definition of Complex Trainset Configurations".

Starting location of loading for first analysis

Defines the starting location of the reference position of the parametric trainset loading on the track for the first analysis for the current Train Loading Group. The location should be defined from the left-most end of the left-hand embankment which is at a location of 0.0m. The starting position should allow for the inclusion of any load that is to the left of this position on the track (defined with a negative position in the parametric loading position) or to the right of this position (defined with a positive position in the parametric loading position). For example, if the parametric trainset loading has been defined from -150m to 150m representing a 300m long trainset centred on the reference position the minimum location for the loading would be +150m relative to the left-most end of the left-hand embankment. Any value less than 150m would mean that it would be impossible to fit the whole of the trainset loading onto the track. Similarly, the maximum location for the loading would be (TotalLengthTrack - 150)m relative to the left-most end of the left-hand embankment.

Finishing location of loading for last analysis

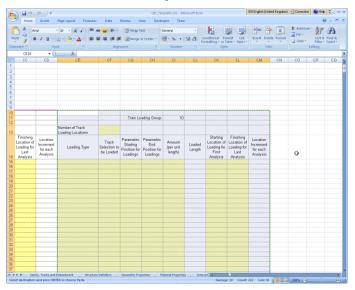
Defines the finishing location of the reference position of the parametric trainset loading on the track for the last analysis for the current Train Loading Group. The location should be defined from the left-most end of the left-hand embankment which is at a location of 0.0m. The finishing position should allow for the inclusion of any load that is to the left of this position on the track (defined with a negative position in the parametric loading position) or to the right of this position (defined with a positive position in the parametric loading position). The limits of the finishing location are identical to those for the starting location discussed above.

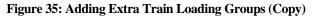
Location increment for each analysis

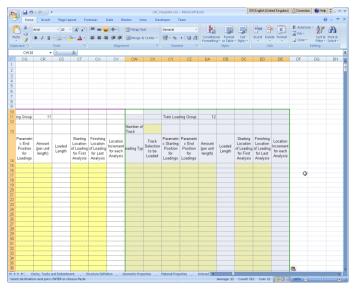
The location increment for the loading for each analysis is automatically calculated from the starting and finishing locations of the loading and the defined number of track loading locations. All of the loading for a given track should have the same increment to ensure that each component of the loading moves as a group. Generally the starting and finishing locations for the reference position of the loading for a given track should be identical for that track. Different location increments are possible between tracks when more than one track is analysed with positive location increments indicating that the trainset is moving from left to right and negative location increments indicating that the trainset is moving from right to left.

For a single track structure the trainset loading may be stationary (location increment = 0.0m) but for this condition the number of track loading locations <u>must</u> be set to 1. For

a two track structure, one of the trainsets on one of the tracks may be stationary but an error will result if both of the trainsets loading the track are stationary if the number of track loading locations is greater than 1. To analyse two stationary trainsets on a two track structure the number of track loading locations <u>must</u> be set to 1.









Rail Track Analysis Menu Options

The Rail Track Analysis option is accessed through the Bridge menu by selecting the Rail Track Analysis UIC774-3 entry. This menu entry provides the following three options:

- Build Model...
- □ Apply Rail Loads...
- **Extract Results To Excel...**

Build Model Dialog

UIC774-3 Model Builder		×
Model filename		
Microsoft Excel spreadsheet or batch text file	Browse	
NOTE: LUSAS model will be built	and run in the current working directory	
Current working directory: C:\Pr	ojects\J12504\TrackStructureInteraction	
Element size 1.0	-	
Apply temperature and rail lo	ads in same analysis	
🔽 Wait for solution		
	OK Cancel Help	

Figure 37: UIC774-3 Model Builder Dialog

- □ **Model filename** The model filename for the analysis should be entered into the box if batch processing is not being used (see below). The file should not contain any folder specification as all models created will be placed in the current working folder indicated on the dialog.
- □ Microsoft Excel spreadsheet or batch text file If batch processing is not being used and a single model is being created, the filename of the Microsoft Excel spreadsheet that will be used to define the analysis must be entered into the box (including file extension). If no folder structure is specified the spreadsheet should be located in the current working folder. Alternatively, the Browse... button may be used to locate the spreadsheet.

If batch processing of multiple models is being performed then a batch text file listing the Microsoft Excel spreadsheets to use for defining the models should be entered into the box (must have a *.txt file extension). The batch text file can be entered explicitly

into the dialog or located using the Browse... button and selecting "Batch text file (*.txt)" as the file type.

The format of the batch text file is indicated below and simply contains a TAB delimited list of the Microsoft Excel files to build the models from and an optional LUSAS model name (if no model name is supplied the basename of the Microsoft Excel spreadsheet will be used) with one model entry per line. If no folder structure is defined for the Microsoft Excel files then the current working folder will be assumed to contain the spreadsheet files, otherwise they may exist at any folder level on the computer system. If a spreadsheet file cannot be found or contains invalid data it will be skipped in the batch processing and an error reported in the "UIC774-3_BuildModel.log" file created in the current working folder. Blank lines are ignored and batch processing will terminate at the end of the batch text file. The number of

analyses in the batch process is unlimited. In the example below the first model built from the Bridge1.xlsx spreadsheet will be

called LUSAS_Bridge1.mdl, the second model will take its basename from the Microsoft Excel spreadsheet and will be called Bridge2.mdl and the third model will be called RTA_Bridge3.mdl.

```
Bridge1.xlsx LUSAS_Bridge1
..\SomeFolder\Bridge2.xlsx
D:\Project\Spreadsheet\Bridge3.xlsx RTA Bridge3
```

Figure 38: Example Batch Text File With Three Bridges To Build

□ Element Size The element size to use in the Finite Element mesh should be specified in this box. According to the UIC774-3 Code of Practice, the maximum element size that is permitted in an analysis is 2.0m (Clause 1.7.3). The dialog therefore generally allows element sizes of 0 < Element Size ≤ 2.0m for the building of the models. Larger element sizes can be used (up to the length of the smallest bridge deck span) but a warning will be issued about non-compliance with the UIC774-3 Code of Practice.</p>



Note. For large bridges and/or embankments the use of small element sizes can generate excessively large models which take significant time to manipulate / solve. Use of element sizes below 1.0m should be used with caution.

- □ Apply temperature and rail loads in same analysis Two analysis types are available from the model building dialog. These are:
 - The solution of the combined temperature and rail loading effects (option turned on)
 - The solution of just the temperature effects (option turned off)

If only a single rail loading configuration is going to be analysed for a particular model then this option should be switched <u>on</u>.

If, on the other hand, a range of rail loading configurations needs to be applied to a model (for different train positions with varying braking / accelerating loading configurations) then this option should be turned <u>off</u> to allow the rail loads to be applied separately by the **Apply Rail Loads** dialog described below.

Building a model to solve only temperature effects also allows the model to be updated prior to applying the rail loading. A situation where this may be needed is the case of a mixed bridge type (for example, one having concrete and steel sections) where the temperature loading of the bridge/deck cannot be classified by the single temperature change available in the Microsoft Excel spreadsheet. If only the temperature model is built, additional temperature loading attributes can be defined and assigned to the temperature loadcase prior to the rail load application.

Solving only the temperature effects will also allow the support conditions to be modified for pier foundations that require rotational stiffness rather than rigidity (see the discussion of Structure Definition section of the Microsoft Excel spreadsheet) or the addition of varying sections to the decks and spans of the structure.



Note. Models created from spreadsheet data contain named groups that are used in the creation of results worksheets. Care should be taken to avoid making major changes to the layout of the model and the loadcases, otherwise the application of the rail loading may fail.

□ Wait for solution If the option to wait for the solution is selected then all of the analyses will be run from Modeller and nothing can be carried out in the current Modeller window until the solution has finished. For relatively small structures or analyses with a limited set of parametric trainset loading locations this is may be fine. If a large number of parametric trainset loading locations are included in an analysis and/or a large number of models are being built using the batch processing then waiting for the solution can take a considerable amount of time. Under this situation the wait for solution option can be turned off which will cause the analyses to be built and run but the Modeller application will be free for additional tasks.



Caution. You should not attempt to run another rail track analysis in the same folder as an existing analysis is being built or solved. Attempting to do this will corrupt the current analysis that is being built or solved. If sufficient rail track analysis licenses are available on the machine that is being used then additional rail track analyses can be performed so long as each analysis is performed in a different folder.

Apply Rail Loads Dialog

UIC774-3 Apply Rail Loads		×
Apply train loads to current mo	odel	
Original model filename	E	Browse
Rail load model filename		
Rail load Microsoft Excel spreadsheet or batch text file	E	Browse
☑ Wait for solution		
	OK Cancel	Help

Figure 39: UIC774-3 Apply Rail Loads Dialog

If the bridge model was built and solved with only the temperature loads (**Apply temperature and rail loads in same analysis** turned off in model building dialog) then this model can subsequently be used for applying rail load configurations using this dialog. The dialog should not be used for models that have been built with both the temperature and rail loading applied and will report an error if attempted.

- □ Apply train loads to current model If the current model loaded was generated from the Build Model... dialog with the Apply temperature and rail loads in same analysis option turned off then this option can be selected. If this option is not selected then the Original model filename entry is available for manual selection of the original model containing only temperature loads.
- □ Original model filename If a single rail load configuration is to be analysed and the currently loaded model is not being used, the original model filename should be entered into the box. Alternatively, the Browse... button can be used to locate the original model file containing only the temperature loading. For batch processing the original model filename is ignored.
- □ Rail load model filename If a single rail load configuration is to be analysed the new filename for the model incorporating the temperature and rail loads should be entered into the box. This filename can contain the path name for the model location (folder must exist) but should generally only have the filename defined which will then be saved in the current working folder. This filename can be the same as the original model filename but should generally be different to allow the temperature loading model to be reused for another rail load configuration. For batch processing the new rail load model filename is ignored.
- □ Rail load Microsoft Excel spreadsheet or batch text file If a single rail load configuration is to be analysed for the specified bridge model the filename of the Microsoft Excel spreadsheet containing the required loading should be entered into the box. Alternatively the Browse... button can be used to locate

the file. Once the spreadsheet has been specified the OK button can be clicked to carry out the modification of the original bridge model to include the combined effects of the temperature and rail loading.

If multiple models and/or multiple rail load configurations are to be analysed then only the batch text file (which must have a *.txt file extension) listing the information required by the software should be entered into this box. Alternatively, the Browse... button can be used, selecting "Batch text file (*.txt)" as the file type.

For each model/rail configuration analysis the batch text file should contain a separate line of data. Each line should specify the original temperature model, the new combined loading model to create and the Microsoft Excel spreadsheet that contains the rail configuration definition. Each item on a line should be TAB delimited to allow spaces to be used in the filenames. An example batch text file is shown below.

Bridge1.mdl	Bridge1_RailConfig1.mdl	Bridge1_RailConfig1.xls
Bridge1.mdl	Bridge1_RailConfig2.mdl	Bridge1_RailConfig2.xls
Bridge1.mdl	Bridge1_RailConfig3.mdl	Bridge1_RailConfig3.xls
Bridge1.mdl	Bridge1_RailConfig4.mdl	Bridge1_RailConfig4.xls
Bridge2.mdl	Bridge2_RailConfig1.mdl	Bridge2_RailConfig1.xls
Bridge2.mdl	Bridge2_RailConfig2.mdl	Bridge2_RailConfig2.xls
Bridge3.mdl	Bridge3_RailConfig1.mdl	Bridge3_RailConfig1.xls

Figure 40: Sample Rail Loading Batch Text File

In the above example, three different bridge deck temperature models have been selected and four rail load configurations analysed for the first, two rail load configurations for the second and one rail load configuration for the third. The number of entries in the batch text file is unlimited and batch processing will terminate once the end of the file is reached. If any analysis fails due to missing or invalid files an error will be reported to the "UIC774-3_RailLoads.log" file in the current working folder.



Note. If the batch text file method is being used the **Apply train loads to current model** option will be ignored since the list of temperature only models to use for the applying of the rail loads for each of the analyses is contained within the batch text file.

□ Wait for solution If the option to wait for the solution is selected then all of the analyses will be run from Modeller and nothing can be carried out in the current Modeller window until the solution has finished. For relatively small structures or analyses with a limited set of parametric trainset loading locations this is may be fine. If a large number of parametric trainset loading locations are included in an analysis and/or a large number of models are being built using the batch processing then waiting for the solution can take a considerable amount of time. Under this situation the wait for solution option can be turned off which will

cause the analyses to be built and run but the Modeller application will be free for additional tasks.



Caution. You should not attempt to run another rail track analysis in the same folder as the one where an existing analysis is being built or solved. Attempting to do this will corrupt the current analysis that is being built or solved. If sufficient rail track analysis licenses are available on the computer that is being used then additional rail track analyses can be performed so long as each analysis is performed in a different folder.

Extract Results To Microsoft Excel Dialog

UIC774-3 Post Processor	x
Filename	
Working folder	
Save in C:\Projects\J12504\TrackStructureInteraction Browse]
WARNING: Do not perform any Copy & Paste actions during the post- processing as this could lead to incorrect extraction and processing of the results by Microsoft Excel	
OK Cancel Help	

Figure 41: UIC774-3 Post Processor Dialog

A dedicated post-processing dialog is provided that allows the automatic extraction of the results from the track/bridge interaction analysis to a Microsoft Excel spreadsheet. On start-up, if nothing is selected in Modeller, the dialog will inspect the active model to ensure that there are results present and also detect whether the UIC774-3 groups defined during the model building process are present in the Groups Treeview. For this reason any manual editing of the model should be kept to a minimum and the "Track 1", "Track 2", "Decks" and interaction joint groups should not be modified or renamed.

- □ **Filename** The filename for the Microsoft Excel spreadsheet that will be created should be entered into this box. The filename must not have any folder structure specified as the file will be placed in the folder selected below.
- □ Working folder / Save In If the spreadsheet is to be saved in a folder other than the current working folder then the User defined option can be selected and the required folder entered into the box or browsed for using the ... button.
- □ After clicking **OK** the option to carry out enveloping of results within Excel is available.



Note. When large models and / or large numbers of results files are being postprocessed then the time required for the post-processing can become significant due to the amount of data that is transferred between Modeller and Microsoft Excel. During the post-processing it will not be possible to perform any other tasks in Modeller.



Caution. You should not have any other Microsoft Excel windows open while the post-processing is carried out. Starting Microsoft Excel or opening another Microsoft Excel spreadsheet while the post-processing is running will break the connection between Modeller and Microsoft Excel resulting in an error and termination of the post-processing.

Rail Track Analysis Results Spreadsheet

The results spreadsheet contains worksheets of results for specific areas of interest. The number of worksheets created will depend upon the number of tracks and decks modelled and whether enveloping of results was selected.

In using the Rail Track Analysis post-processor dialog the post-processing carried out is dependent upon whether any selections have been made in LUSAS Modeller. The Rail Track analysis post-processor can carry out:

- □ Post-processing of automatically defined groups (when no selections have been made in Modeller)
- Dest-processing of selected track / rail nodes
- **D** Post-processing of selected lines if groups are missing

Results worksheets created

The spreadsheet created will contain worksheets that typically include results for :

- **Track 1, 2**
- Deck 1, 2, 3 etc
- □ Envelope, Track 1, 2
- □ Envelope, Deck 1, 2, 3 etc
- **Railbed Check**
- **Longitudinal Reactions Check**
- □ Rail Stresses Check

And , if more than one deck is defined in the model additional results for:

- **Deck End Longitudinal Displacements (axial, end rotations and total)**
- Deck End Vertical Displacements

Post-processing of automatically defined groups

If nothing is selected in the Modeller window and all of the UIC774-3 groups are present in the Groups Treeview then separate results worksheets are generated for the tracks/rails and decks. If more than one results file is loaded, no combinations or envelopes are defined in the LUSAS model and enveloping in Microsoft Excel has

been selected then additional envelope results output is generated in separate results worksheets.

If basic combinations or envelopes were defined in the LUSAS model the results from these are output to the tracks/rails and decks worksheets in addition to the temperature only and combined temperature and train loading results. If enveloping in Microsoft Excel has been selected then an additional envelope will be generated for the basic combinations included in the model (and these results will be included in the overall envelope of all results). LUSAS envelopes will not be included in the Microsoft Excel enveloping.



Note. Basic combinations that contain only pure loadcases can be post-processed but basic combinations that contain envelopes or smart combinations cannot be post-processed. Envelopes cannot be post-processed if they contain smart combinations. It should, however, be noted that combinations of nonlinear results (such as those from the Rail Track Analysis tool) is not strictly valid and results should be used with caution.

Rail Track Results

A separate results worksheet is created for each track in the model. In this worksheet the displacement (including railbed relative displacement), forces / moments and axial stresses in the track rails are reported for all of the results files. If only temperature results exist in a results file the post-processing will only generate the output for these (Increment 1 of the nonlinear analysis), Figure 42 to Figure 44. If trainset loading is also present in the analyses then for each results file the results for the temperature only (Increment 1 of the nonlinear analysis) and the combined temperature and trainset loading (Increment 2 of the nonlinear analysis) are output for each results file, Figure 45 to Figure 47.

Figure 48 shows a zoomed out version of the worksheet showing the output for multiple results files. In this figure the temperature only and combined results for two results files are illustrated with the analyses incrementing from left to right and for each, the first column of results and graphs are for the temperature only case and the second column are for the combined case for each analysis.



Note. When only a single Train Loading Group is analysed the results and charts will report results / chart titles as "Position ? – Deck Temp (Manual NL)" or "Position ? – Train Loads". For analyses where multiple Train Loading Groups are included then each of the results / chart titles will reflect the Train Loading Group and position with text such as "Train Loading Group ? – Position ? – Train Loads" to identify the results and charts within the post-processing spreadsheet (and provide fully titled charts should these be copied and pasted from the spreadsheet).

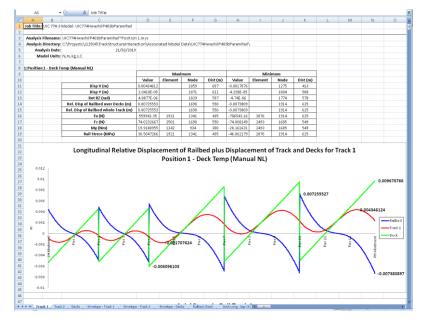


Figure 42: Track Worksheet Summary and Railbed Graph for Temperature Only Results of Analysis, Increment 1 (1 of 3)

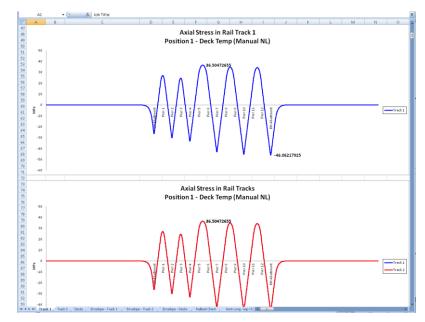


Figure 43: Track Worksheet Rail Stress Graphs for Temperature Only Results of Analysis, Increment 1 (2 of 3)

	A	B	C	D	E	F	G	н	1	J	K	L	M	N	0
99	Element	Node	Abutment / Pier	Distance (m)	X (m)	¥ (m)	Z (m)	Disp X (m)	Disp Y (m)	Rot RZ (rad)	Rel. Disp of Railbed (m)	Fx (N)	Fz (N)	My (Nm)	Rail Stres (MPa)
00	39	33		0	-300	0	(0	0	0	0	-3.034E-15	1.212E-209	2.886E-210	-1.978E-
01	39	38		1	-299	0	(-9.42E-25	9.172E-219	1.113E-216	-9.42E-25	-3.034E-15	1.212E-209	2.886E-210	-1.978E-2
02	44	38		1	-299	0	(-9.42E-25	9.172E-219	1.113E-216	-9.42E-25	-3.11E-15	-4.49E-209	-1.35E-209	-2.027E-
03	44	39		2	-298	0	(-1.907E-24	-2.43E-218	-4.63E-216	-1.907E-24	-3.11E-15	-4.49E-209	-1.35E-209	-2.027E-
04	48	39		2	-298	0	(-1.907E-24	-2.43E-218	-4.63E-216	-1.907E-24	-3.262E-15	1.76E-208	5.203E-209	-2.127E-
05	48	43		3	-297	0	(-2.92E-24	9.113E-218	1.81E-215	-2.92E-24	-3.262E-15	1.76E-208	5.203E-209	-2.127E-
06	51	43		3	-297	0	(-2.92E-24	9.113E-218	1.81E-215	-2.92E-24	-3.496E-15	-6.85E-208	-2.03E-208	-2.279E-
07	51	46		4	-296	0	(-4.005E-24	-3.55E-217	-7.05E-215	-4.005E-24	-3.496E-15	-6.85E-208	-2.03E-208	-2.279E-
08	56	46		4	-296	0	(-4.005E-24	-3.55E-217	-7.05E-215	-4.005E-24	-3.816E-15	2.669E-207	7.892E-208	-2.488E-
09	56	49		5	-295	0	0	-5.19E-24	1.381E-216	2.746E-214	-5.19E-24	-3.816E-15	2.669E-207	7.892E-208	-2.488E-
10	59	49		5	-295	0	(-5.19E-24	1.381E-216	2.746E-214	-5.19E-24	-4.232E-15	-1.04E-206	-3.07E-207	-2.759E-
11	59	52		6	-294	0					-6.504E-24				
12	63	52		6	-294	0					-6.504E-24				
13	63	55		7	-293	0					-7.979E-24				
14	67	55		7	-293	0					-7.979E-24			-4.66E-206	
15	67	58		8	-292	0					-9.653E-24			-4.66E-206	
16	71	58		8	-2.92	0		-9.653E-24			-9.653E-24			1.016E-205	
17	71	62		9	-291	0					-1.157E-23				
18	76	62		9	-291	0					-1.157E-23				
18	76	62		10	-291	0					-1.377E-23				
20	76	65		10	-290	0									
											-1.377E-23				
21	79	66		11	-289	0					-1.631E-23				
22	83	66		11	-289	0					-1.631E-23				
23	83	71		12	-288	0					-1.926E-23				
24	87	71		12	-288	0					-1.926E-23				
25	87	72		13	-287	0								4.177E-203	
26	91	72		13	-287	0					-2.268E-23			-1.63E-202	
27	91	77		14	-286	0		-2.667E-23			+2.667E-23			-1.63E-202	
28	95	77		14	-286	0	(-2.667E-23	-2.85E-211	-5.66E-209	-2.667E-23	-1.498E-14	2.143E-201	6.336E-202	-9.767E
29	95	79		15	-285	0	(-3.132E-23	1.109E-210	2.205E-288	-3.132E-23	-1.498E-14	2.143E-201	6.336E-202	-9.767E
30	99	79		15	-285	0	(-3.132E-23	1.109E-210	2.205E-208	-3.132E-23	-1.749E-14	-8.34E-201	-2.47E-201	-1.14E
31	99	83		16	-284	0	(-3.675E-23	-4.32E-210	-8.59E-288	-3.675E-23	-1.749E-14	-8.34E-201	-2.47E-201	-1.14E
32	104	83		16	-284	0	(-3.675E-23	-4.32E-210	-8.59E-208	-3.675E-23	-2.043E-14	3.25E-200	9.61E-201	-1.332E
33	104	84		17	-283	0	(-4.309E-23	1.682E-209	3.344E-207	-4.309E-23	-2.043E-14	3.25E-200	9.61E-201	-1.332E
34	107	84		17	-283	0	(-4.309E-23	1.682E-209	3.344E-207	-4.309E-23	-2.388E-14	-1.27E-199	-3.74E-200	-1.557E
35	107	87		18	-282	0	(-5.05E-23	-6.55E-209	-1.3E-206	-5.05E-23	-2.388E-14	-1.27E-199	-3.74E-200	-1.557E
36	112	87		18	-282	0	(-5.05E-23	-6.55E-209	-1.3E-206	-5.05E-23	-2.792E-14	4.93E-199	1.458E-199	-1.82E
37	112	91		19	-281	0	(-5.917E-23	2.551E-208	5.072E-206	-5.917E-23	-2.792E-14	4.93E-199	1.458E-199	-1.82E-
38	116	91		19	-281	0	(-5.917E-23				-2.129E
39	116	94		20	-280	0			-9.93E-208		-6.931E-23				
10	119	94		20	-280	0					-6.931E-23				-2.49E
41	119	96		20	-279	0					-8.116E-23				-2.49E
42	123	96		21	-279	0					-8.116E-23				
42	123	99		22	-278	0			-1.51E-206		-9.504E-23				

Figure 44: Track Worksheet Tabulated Output for Temperature Only Results of Analysis, Increment 1 (3 of 3)

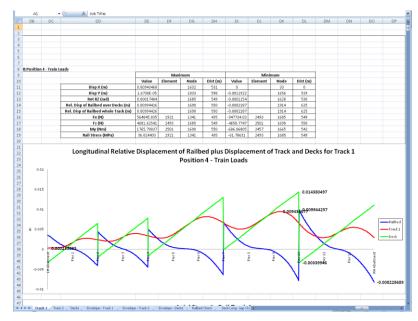


Figure 45: Track Worksheet Summary and Railbed Graph for Temperature and Trainset Results of Analysis, Increment 2 (1 of 3)

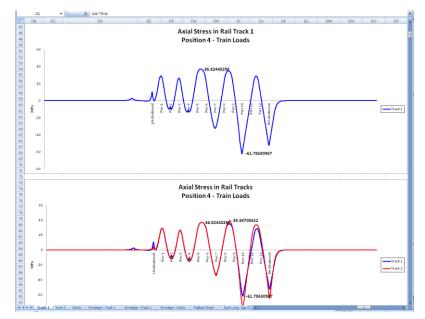


Figure 46: Track Worksheet Rail Stress Graphs for Temperature and Trainset Results of Analysis, Increment 2 (2 of 3)

	DB	DC	DD	DE	DF	DG	DH	DI	DJ	DK	DL	DM	DN	DO	DP
99	Element	Node	Abutment / Pier	Distance (m)	X (m)	¥ (m)	Z (m)	Disp X (m)	Disp Y (m)	Rot RZ (rad)	Rel. Disp of Railbed (m)	Fx (N)	Fz (N)	My (Nm)	Rail Stre (MPa)
00	39	33		0	-300	0	(0	0	0	0	1.9998E-12	-9.82E-175	-2.34E-175	1.3037E
01	39	38		1	-299	0	(6.2083E-22	-7.43E-184	-9.02E-182	6.2083E-22	1.9998E-12	-9.82E-175	-2.34E-175	1.3037E
02	44	38		1	-299	0	(6.2083E-22	-7.43E-184	-9.02E-182	6.2083E-22	2.0495E-12	3.641E-174	1.095E-174	1.3361E
03	44	39		2	-298	0	(1.2571E-21	1.971E-183	3.752E-181	1.2571E-21	2.0495E-12	3.641E-174	1.095E-174	1.3361E
04	48	39		2	-298	0	(1.2571E-21	1.971E-183	3.752E-181	1.2571E-21	2.15E-12	-1.43E-173	-4.22E-174	1.4017E
05	48	43		3	-297	0	6	1.9246E-21	-7.38E-183	-1.47E-180	1.9246E-21	2.15E-12	-1.43E-173	-4.22E-174	1.4017E
06	51	43		3	-297	0	(1.9245E-21	-7.38E-183	-1.47E-180	1.9246E-21	2.304E-12	5.553E-173	1.642E-173	1.5021E
87	51	46		4	-296	0	(2.6398E-21	2.873E-182	5.713E-180	2.6398E-21	2.304E-12	5.553E-173	1.642E-173	1.5021E
80	56	45		4	-296	0	(2.6398E-21	2.873E-182	5.713E-180	2.6398E-21	2.5152E-12	-2.16E-172	-6.39E-173	1.6397E
09	56	49		5	-295	0			-1.12E-181						
10	59	49		5	-295	0	(3.4206E-21	-1.12E-181	-2.23E-179	3.4206E-21	2.7888E-12	8.422E-172	2.49E-172	1.8181E
11	59	52		6	-294	0			4.357E-181						
12	63	52		6	-294	0			4.357E-181						
13	63	55		7	-293	0	1	5.2587E-21	-1.7E-180	-3.37E-178	5.2587E-21	3.1318F-12	-3.28E-171	-9.7E-172	2.0417E
14		55		7	-293	0		5.2587E-21			5.2587E-21				
15	67	58		8	-292	0			6.609E-180						
16		58		8	-292	0			6.609E-180						
17	71	62		9	-291	0			-2.57E-179						
18		62		9	-291	0			-2.57E-179						
19	76	65		10	-290	0			1.002E-178						
20		65		10	-290	0			1.002E-178						
20	79	66		11	-290	0		1.0748E-20			1.0748E-20				
		66		11	-205	0		1.0748E-20			1.0748E-20				
23		71		11	-288	0			1.521E-177						
23 24		71		12	-288	0			1.521E-177 1.521E-177						
24 25	87	72		12									-1.14E-167		
					-287	0			-5.92E-177						
26	91	72		13	-287	0			-5.92E-177						
27	91	77		14	-286	0			2.306E-176						
28		77		14	-286	0			2.306E-176						
29		79		15	-285	0			-8.98E-176						
30	99	79		15	-285	0			-8.98E-176						
31	99	83		16	-284	0	0		3.498E-175						
32	104	83		16	-284	0			3.498E-175						
33		84		17	-283	0	(-1.36E-174				-2.63E-165		
34		84		17	-283	0	(-1.36E-174				1.026E-164		
35		87		18	-282	0			5.306E-174						
36		87		18	-282	0			5.306E-174						
37		91		19	-281	0			-2.07E-173						
38		91		19	-281	0			-2.07E-173					4.6E-164	
39		94		20	-280	0			8.048E-173					4.6E-164	
40	119	94		20	-280	0			8.048E-173						
41	119	96		21	-279	0			-3.13E-172						
42		96		21	-279	0	6	5.349E-20	-3.13E-172	-6.23E-170	5.349E-20	2.9451E-11	2.359E-162	6.977E-163	1.92E
43	123	99		22	-278	0	0	6.2633E-20	1.221E-171	2.428E-165	6.2633E-20	2.9451E-11	2.359E-162	6.977E-163	1.92E

Figure 47: Track Worksheet Tabulated Output for Temperature and Trainset Results of Analysis, Increment 2 (3 of 3)

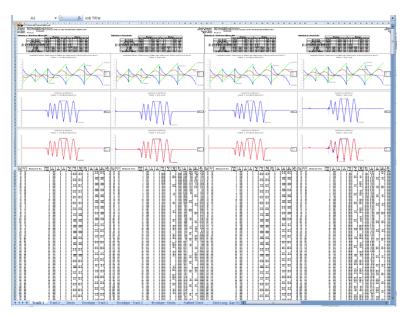


Figure 48: Track Worksheet for Multiple Results Files

If valid basic combinations or envelopes that match the criteria described in Postprocessing of automatically defined groups (page 40) are present in the model then additional results for these will be tabulated into the Microsoft Excel worksheets for the tracks. For basic combinations a warning will be added at the top of the extracted results indicating that basic combinations of nonlinear results are not strictly valid. For envelopes all quantities other than the railbed displacements will be calculated for the tracks but the results from LUSAS envelopes will be excluded from any enveloping carried out in Microsoft Excel.

Deck Results

A separate worksheet is created for the deck in the model. In this worksheet the displacement and forces / moments in the deck are reported for all of the results files. If only temperature results exist in a results file the post-processing will only generate the output for these (Increment 1 of the nonlinear analysis). If trainset loading is also present in the analyses then for each results file the results for the temperature only (Increment 1 of the nonlinear analysis) and the combined temperature and trainset loading (Increment 2 of the nonlinear analysis) are output for each results file. Figure 49 to Figure 52 show the tabulated and graph output generated for the deck for all of the loading conditions included in the analyses. Figure 53 shows a zoomed out version of the worksheet showing the output for multiple results files. In this figure the temperature only and combined results for more than two results files are illustrated with the analyses incrementing from left to right and for each, the first column of results and graphs are for the temperature only case and the second column are for the combined case for each analysis.

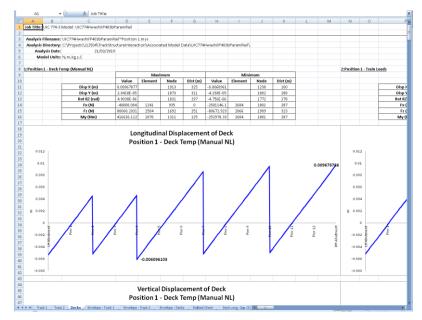


Figure 49: Deck Worksheet Summary and Longitudinal Displacement Graph for Results of Analysis (1 of 4)

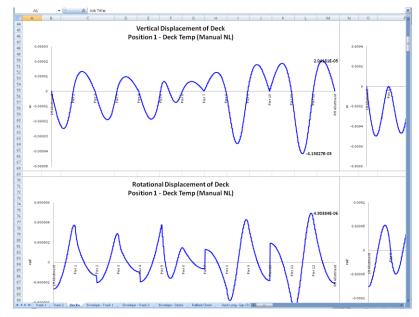


Figure 50: Deck Worksheet Vertical and Rotational Displacement Graphs for Results of Analysis (2 of 4)

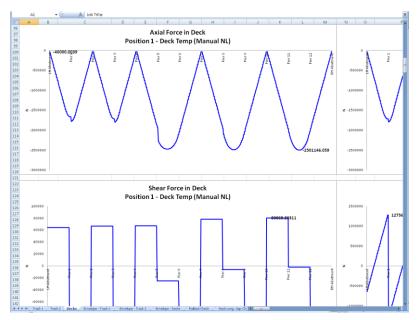


Figure 51: Deck Worksheet Axial and Shear Force Graphs for Results of Analysis (3 of 4)

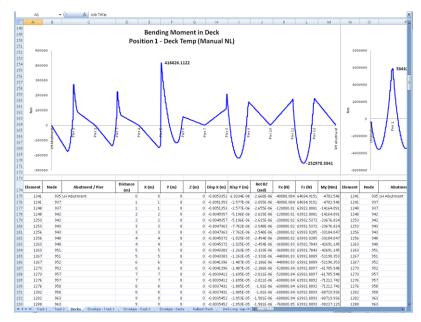


Figure 52: Deck Worksheet Bending Moment Graph and Tabulated Output for Results of Analysis (4 of 4)

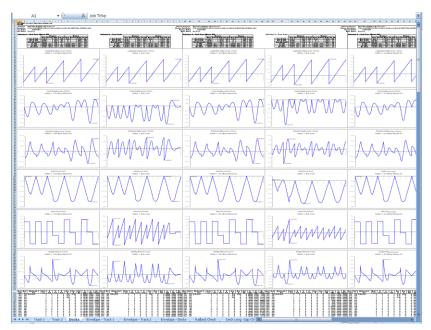


Figure 53: Deck Worksheet for Multiple Results Files

If valid basic combinations or envelopes that match the criteria described in **Post-processing of automatically defined groups** (page 40) are present in the model then additional results for these will be tabulated into the Microsoft Excel worksheets for the decks. For basic combinations a warning will be added at the top of the extracted results indicating that basic combinations of nonlinear results are not strictly valid. For envelopes all quantities will be calculated for the decks but the results from the LUSAS envelopes will be excluded from any enveloping carried out in Microsoft Excel.

Additional Results from Enveloping in Microsoft Excel

If more than one results file is loaded, basic combinations are defined in the model that may be post-processed (see the restrictions under the **Post-processing of automatically defined groups** section on page 40) and enveloping in Microsoft Excel has been selected then additional envelope results output is generated by the post-processor in separate worksheets in Microsoft Excel. These additional worksheets include envelopes of the raw results and summary tables for key results that are required for checking against the UIC774-3 code. The track and deck envelopes produce the same summary tables, graphs and results highlighted in the previous two sections for the following envelopes:

- □ Maximum and minimum envelopes for temperature loading only
- □ Maximum and minimum envelopes for temperature and trainset rail loading

- □ Maximum and minimum envelopes for all of the basic combinations defined in the model (if valid basic combinations are present)
- □ Maximum and minimum envelopes for all configurations (an envelope of all of the above results)

The additional UIC774-3 summary tables output by the post-processor are dependent upon the configuration of the model (the number of tracks and the number of decks in the structure) but will include some or all of the following tables:

- □ Longitudinal Relative Displacement of Railbed (Relative Displacement between Rails and Deck)
- **D** Longitudinal Relative Displacement between Ends of Decks (Axial)
- □ Longitudinal Relative Displacement between Ends of Decks (End Rotations)
- **D** Longitudinal Relative Displacement between Ends of Decks (Total Effects)
- □ Vertical Relative Displacement between Ends of Decks
- □ Longitudinal Reactions
- □ Axial Rail Stress



Note. The 'total effect' longitudinal relative displacement between the ends of the decks is the sum of the axial movement of the deck support position and the movement of the top of the deck from the rotation of the deck about this support position.

Sample tables are shown in the following figures which provide the peak values, the track that the peak is occurring in (if appropriate), the distance from the left end of the structure of the peak and also a description of where the peak is occurring. In all of the worksheets the worst effects are highlighted in bold and blue text to allow the quick determination of which analysis is causing the worst effects for each of the checks that need to be performed.

	B	ĉ	D	E	F	G	н		J	K	L	M
		Check of Longitudinal Relative Displacement of R	ailbed (Relativ	e Displacement	between Rails	and Deck)						
-												
		UIC 774-3 Model: UIC 774Hwashill Param										
		UIC774Hwashil0Param*Position1-> UIC774Hwashil0Param*Pos	kion 101									
Mo	odel Directory	CAProjects's J12504's Track StructureInteraction										
		26V03/2019 -> 26V03/2019										
	Model Units:	NOROIGS).										
				Track 1			Track 2					
				Distance from	Distance from		Distance from	Distance from	Peak Belative		Distance from	
				Left End of the	Left End of the		Left End of the	Left End of the	Longitudinal	Track Number	Left End of	Descrip
	Analysis ID	Flesults Filename	Loading Type	Model to the	Model to the	Loading Type	Model to the	Model to the	Displacement	with Peak	Structure for	peak lo
				Starting	Finishing		Starting	Finishing	between Rail	Displacement	Peak	peak in
-		UC774HvashittiParam*Position 1mps		Position of the	Position of the		Position of the	Position of the	and Slab (m)		Displacement	
-		UC774HvashittiPiaan Position Lings UC774HvashittiPiaan Position Lings	Temperature Only			Temperature Only	300	600	0.007380897 0.007375343	1	329	FIH Abur FIH Abur
-		UC774HvashilliParam Position Emp	Braking Braking	6.25	300	Accelerating Accelerating	303,25		0.007375295		2 020	FH Abut
+		UC774HvashilliP a am Position 1 mgs	Braking	12.5		Accelerating	300.20	60120	0.007371726		1 100	FPH Abut
-1-	4	UIC776Hvashilt0Param*Position 6.mgs	Enaking	10.75	318.75	Accelerating	309.75	603.75	0.007366432		1 325	FH Abur
-	5	UIC774Hivashill/IParam*Position/Emgs	Braking	21	325	Accelerating	310	613	0.007359531		1 325	FH Abut
1	6	UIC774HvashiIIIParam*Position6.mgs	Braking	31.25	331,25	Accelerating	216.25	616,25	0.007253955			FIH Abutz
1	7	UIC774HvashittiParam*Position7.mgs	Draking	37.5	337.5	Accelerating	219.5	619.5	0.007344906		1 325	FH Abur
1		UIC774HvashittlParam*Position8.mgs	Braking	43.75		Accelerating	322.75		0.007341198		1 325	FH Abut
1	9	UIC774Hvashill/Param*Position8.mgs	Braking	54	350	Accelerating	326	626	0.007343822	1		FH Abut
-	10	UIC774Hvash800P.eam"Position 10.mgs UIC774Hvash800P.eam"Position 10.mgs	Draking	56.25	354.25	Accelerating	329.25	623.25	0.007353003		325	FEH Abute
-		UIC774Hvashit0Param*Position Tunga UIC774Hvashit0Param*Position 12.mes	Braking Braking	62.5	362.5	Accelerating Accelerating	302.5	632.5	0.007357474	1		FEH Aburr FEH Aburr
-1-	2	UC774HvashilliPaam*Position12mgs	Eraking	68.71	383.75	Accelerating	330.75	635./5	0.007361/55	1	325	FH Abut
-1-		UC774HvashilliPixan Position ILmis UC774HvashilliPixan Position Himes	Eraking	0125	100.05	Accelerating	342.25	642.25	0.007369301			Fel Abutr
-	5	UC774HyashittiParam*Position 15 mes	Braking	87.5	387.5	Accelerating	345.5	645.5	0.007375626		305	FH Abut
1	15	UC776Hyashill/Param*Position % mes	Braking	93.75	291.75	Rocelecating	248.75	648.75	0.00738173		2 325	FH Abut
1	17	UIC774Hvashill0Param*Position 17.mgs	Draking	100	400	Accelerating	252	652	0.007388264		2 325	FHI Abur
	13	UC774Hvashill(Param*Position 12.mgs	Braking	106.25	406.25	Accelerating	365.25	655.25	0.007409835		2 325	FH Abutn
		UIC774Hwashilt0Param=Position 19.mgs	Braking	112.5	412.5	Accelerating	358.5	658.5	0.007413397		2 325	FH Aburr
1	50	UIC774Hwashill0IParam*Position 20 mgs	Braking	110.71	418.75	Accelerating	26175		0.007427382			FH Abut
-		UIC774HvashilliPwam*Position21mgs	Draking	125	425	Accelerating	265	665	0.007440419	1		Fier 7
-1-	22	UIC774HvashittParam*Position22mgs UIC774HvashittParam*Position22mes	Evaluing	131.25	431.25	Accelerating	368.25	668.25	0.007539783	1	1 175	Piet 7 Piet 7
-1-		UIC774HvashiltiParam*Position23.mgs UIC774HvashiltiParam*Position24.mes	Braking Braking	107.5		Accelerating	3715		0.007647634		176	Piet 7 Piet 7
+	24	UC774Hvashill@vam"Position24mgs UC774Hvashill@vam"Position25mas	Draking Draking	143.75	443.75	Accelerating	374.75	674,75	0.0079764441		170	Plat 7
+		UC774HyashittiParam Position 25 mgs	Braking	156.25		Accelerating	39125		0.008227912		1 175	Piet 7
+	20	UC776HyashillPaan*Position27764	Eraking	82.5	442.5	Accelerating	30125	604.5	0.0005000		1 175	Plat 7
	29	UC774HvashilliParam*Position28mps	Braking	160.75	461.75	Accelerating	307.75	687.75	0.000014177		1 175	Pier 7
	29	UIC774HyashittitParam*Position.28mps	Braking	125	475	Accelerating	391	691	0.00913004		1 175	Pier 7
1	30	UIC774Hwashilt0Param*Position 30 mps	Braking	191.25	491.25	Accelerating	394,25	694.25	0.009004875		1 175	Fiet 7
		UIC774HvashillIIParam*Position3Lmgs	Braking	107.5	497.5	Accelerating	397.5	697.5	0.008877371		1 175	Piet 7
1		UIC774HvashillIIParam*Position 32.mgs	Braking	190.75		Accelerating	400.75	700.75	0.006794173			Pier?
-		UIC774HvashittiParam*Position 33 mgs	Evaluing	200	500	Accelerating	404	704	0.009590034	1	1 175	Pier 7
-		UIC774Hvashill0Param*Position 34.mgs	Draking	206.25	506.25	Accelerating	407.25	707.25	0.000468225	1	175	Pier 7
+	35	UIC774HvashIIIParam"Position 35 mgs UIC774HvashIIIParam"Position 35 mas	Braking	212.1	512.5	Accelerating Accelerating	410.5		0.008345209		175	Pier 7 Pier 10
+	36	UIC774Hvashill/Param*Position 35 mgs UIC774Hvashill/Param*Position 37 mgs	Braking Braking	218.75		Accelerating	40.75	70./5	0.008579439	1	250	Pher 10 Plan 10
+	37	UC774HvashittiParam*Position 37 mgs UC774HvashittiParam*Position 38 mgs	Braking	20121	540 1910 00	Accelerating	420,25		0.009942548			Pier 10
-	29	UC774Hvashill@wam*Position23mer	Braking	237.5	537.5	Accelerating	4215	7225	0.005929661		1 250	Pier 10
-	40	UC774Hwashill0Pwam*Position40/rws	Braking	243.75	543.75	Accelerating	426.75	728.75	0.009452688		1 250	Pier 10
-	41	UIC774Hwashill0IParam*Position 41.mes	Braking	250	550	Accelerating	430	730	0.009782891		250	Pier 10
	42	UIC774Hwashill0IParam*Position-42,mas	Braking	256.25	556,25	Accelerating	433.25	733.25	0.009525799		1 250	Fier 10
	43	UIC774Hvashill@wam*Position43.mgs	Braking	262.5	562.5	Accelerating	436.5	736.5	0.009455666		1 250	Pier 10
1	44	UIC776HvashiltItParam*Position 66 mgs	Draking	260.75		Accelerating	439.75	739.75	0.009255004			Pier 10
-	45	UIC774Hvashilt0Param*Position+6.mgs	Braking	271	676	Accelerating	443	743	0.009125299	1	250	Pier 10
-	46	UC776-IvashIIIP aram Position 45 mgs UC776-IvashIIIP aram Position 47 mgs	Braking	29125	591,25	Accelerating Accelerating	446,25	746.25	0.009007622 0.009902503			Fler 10 FeH Abute
-	47	UIC774HvashiltIP ar am "Position 47 mgs UIC774HvashiltIP ar am "Position 48 mss	Eraking Eraking	297.5	597.5	Accelerating Accelerating	449.5	749.5	0.009982503	1	325	FEH Abur
+		UC774HvashilliParam*Position49mgs	Braking	200.75		Accelerating	402.75	756	0.003148235	1		FH Abut
+	50	UC774HyashillPaan*Positor51mar	Draking	206.25	001.25	Accelerating	450.25	751,25	0.003041033		325	FPH Abut
1	51	UC776Hvashilt0Paam*Position5Lmgs	Draking	312.5	612.5	Accelerating	462.5	7125	0.009250005			FH Abut
-	52	UIC774Hvashilt0Param*Position52.mes	Braking	318.75	613.75	Accelerating	465.75	765.75	0.009139484		325	FH Aburn
1	52	UC776HvashIIIP x an 'Position 52 mer	Braking	325	625	Accelerating	469	763	0.005/32716		2 225	FH Abut
1	54	UC774Hvashill® wam*Position 54 mes	Draking	331.25	631.25	Accelerating	472.25	772.25	0.009200688		2 326	FH Abur
T		UIC774HwashiltIParam*Position55.mgs	Braking	337.5	637.5	Accelerating	475.5	775.5	0.009223563			FH Abuts
1	56	UIC774Hwashill/Param*Position/56.mgs	Braking	343.75		Accelerating	478.75	778.75	0.003224294	1		FH Abut
1	57	UIC774HvashillIIP a am "Position 57 mgs	Draking	350	650	Accelerating	412	782	0.009230925		225	FPH Abutz
-	58	UIC774HvashillIP a am Position 51 mgs	Braking	356.25		Accelerating	405.25	705.25	0.009236702	1	325	FPH Abutr
-	59	UIC774HvashittiParam*Position53mgs UIC774HvashittiParam*Position90mgs	Exaking Eraking	362.5	662.5	Accelerating	488.5	788.5	0.009237485	1	325	FIH Aburr
+		UC774HvashilliPaam Position Elings	Eraking	388.75		Accelerating	491/5	1 196.00	0.00323045		100	Fel Abur
-	61 62	UC774HyashittiPiram"Position62mgi	Example	381.25	6125	Accelerating	498,25		0.009228364		305	FH Abur
+	62	UC776HyashittiParam*Position\$2mes	Braking	397.5	687.5	Accelerating	5015	8015	0.009221938			FH Abuth
		k Deck Long, Gap Check Axial Deck Long, Gap C	Evaluation	307.5		Accelerating	FOX 78	0003	0.001022/0010			EN Abute

Figure 54: Railbed Check Worksheet for Multiple Results Files

A	В	c	0	E	F	G	н	1	J	к
	-	Check of Longitudinal Relative Displacem		of Decks (Axial	D					
-										
	Job Title:	UIC 774-3 Model: UIC774Hvashil101Param								
Analy	sis Filename:	UIC774Hv ashi101Param*Position 1> UIC774Hv ashi101Para	am [®] Position 101							
Mo	del Directory:	C:@hojects%JI25044TrackStructurePyteraction								
	Analysis Date:	28/03/2019> 28/03/2019								
	Model Units:	N.m.kg.s.C								
_				Track 1			Track 2			
				Distance from	Distance from		Distance from	Distance from	Peak Relative	Pier Numbe
	Analysis ID	Results Filename	Loading Type	Left End of the	Left End of the	Loading Type	Left End of the	Left End of the	Longitudinal	Location
				Model to the	Model to the		Model to the	Model to the	Displacement between Ends of Decks, Positive	Supporting Decks with
		UIC774Headel101Param/Position 1met	Temperature Only	Starting	Finishing	Temperature Only	Starting	Finishing	-0.014506054	
		UC774Heahil0ParamPosition1mea	Braking			Accelerating	300	600		Pier IU
		UIC 7 Perfe admit 0 Planam Position 1 mys	Braking	6.25		Accelerating	303.25			
		UIC774Hxashi101Param/Postion 2 mys	Braking	12.5	306.23	Accelerating	305.25			
		UIC 714Hwashi101Param Position 3.mys	Braking	18.75	312.3	Accelerating	308.75	600.75	-0.014917903	Pieriu
		UIC774Hy ashi/101Param Position 5 mvs	Braking	25	220	Accelerating	313	613	-0.014926743	Pine 10
		UIC 774He add/01Param/Position 6 mus	Braking	31.25		Accelerating	316.25			
	7	UIC 774Hwashi101Param Position 0.mys	Braking	37.5	3976	Accelerating	319.5	613.5	-0.014336104	Play 11
		UC774Hy ashi101Param Position 8 mvs	Braking	43.75	343.77	Accelerating	322.75	622.75	-0.014953949	Pier 10
		UIC774Hy ashi 101Paran Postion 3 mus	Braking	50	350	Accelerating	326			
		UIC774Hy ashi/101Param/Position 10, mut	Braking	56.25		Accelerating	329.25			
		UIC774Hwashi101Param*Position 11.mss	Braking	62.5		Accelerating	332.5	632.5		
		UIC774He ashi/101Param*Position 12.mgs	Braking	68.75		Accelerating	335.75			
	13	UIC774He adul/101Param/Position 13.mut	Braking	75		Accelerating	339			
		UIC774Hwashil101Param/Position 14.mvs	Braking	81.25	391.25	Accelerating	342.25	642.25		Pier 10
	15	UIC774Hwashi101Param*Position 15.mvs	Braking	87.5	387.5	Accelerating	345.5	645.5	-0.015091519	Pier 10
	16	UIC 774He ashi/101Param Position 16.mss	Braking	33.75	393.75	Accelerating	348.75	648.75	-0.015115078	Pier 10
	17	UIC774Hwashi/101Param/Position 17.mus	Braking	100	400	Accelerating	352	652	-0.015140059	Pier 10
	18	UIC774Hwashi101Param'Position 18.mvs	Braking	106.25	406.25	Accelerating	355.25	655.25	-0.015186563	Pier 10
	19	UIC774He ashi/101Param Position 13.mss	Braking	112.5	412.5	Accelerating	358.5	658.5	-0.075228264	Pier 10
	20	UIC774Hs ashi/101Param'Position 20.mus	Braking	118.75	418.71	Accelerating	361.75	661.75	-0.015269024	Pier 10
	21	UIC774Hwashil101Param'Position 21 mus	Braking	125	425	Accelerating	365	665	-0.015401339	Plet 7
	22	UIC774Hwashi101Param*Position 22 mvs	Braking	131.25	431.25	Accelerating	368.25	668.25	-0.01557328	Pier 7
	23	UIC774His ashi/101Param Position 23.mys	Braking	137.5	437.1	Accelerating	371.5		-0.015758342	Pier7
	24	UIC774Hirashi101Param'Position 24.mys	Braking	143.75	443.75	Accelerating	374.75	674.75	-0.015955933	Pier 7
	25	UIC774Hwashi101Param*Position 25.mys	Braking	150	450	Accelerating	378	678	-0.016154187	Pier 7
		UIC774Hwashi101Param Position 26.mys	Braking	156.25	456.25	Accelerating	381.25	601.25	-0.016333193	
	27	UIC774He ashi/01Param*Position 27.mys	Braking	162.5	462.5	Accelerating	384.5		-0.016539634	Pier7
	28	UIC774Hwashi101Param'Position 28.mys	Braking	168.75	468.75	Accelerating	387.75	687.75	-0.016755675	Pier7
	29	UIC774Hwashi101Param*Position 28.mys	Braking	175	475	Accelerating	391	69	-0.016910744	Pier 7
		UIC774Hwashi101Param*Position 30.mys	Braking	101.25		Accelerating	394.25			
		UIC774Hwashil101Param/Position 31 mys	Braking	187.5		Accelerating	397.5	697.5		
	32	UIC774Hwashi101Param'Position 32 mys	Braking	193.75	493.75	Accelerating	400.75	700.75		
	33	UIC774Hwashi101Param*Position 33.mps	Braking	200	500	Accelerating		704	-0.016594624	
		UIC774Hwashil101Param/Position 34.myz	Braking	206.25	506.25	Accelerating	407.25			
		UIC774Hwashi/101Param/Position 35.mys	Braking	212.5	512.5	Accelerating	410.5			
	36	UIC774Hwashi101Param*Position 36.mss	Braking	218.75	518.75	Accelerating	413.75	713.75	-0.017087318	Pier 10
	37	UIC774Hwashil101Param*Position 37.mys	Braking	225		Accelerating	417		-0.017255659	Pier 10
	38	UIC774His adul/101Param/Position 38 mys	Braking	231.25		Accelerating	420.25			
		UIC774Hwashi101Param/Position 33 mus	Braking	237.5	537.5	Accelerating	423.5			
	40	UC774Hx ashi101Param [®] Position 40.mys UIC774Hx ashi1101Param [®] Position 41.mys	Braking	243.75	543.75	Accelerating Accelerating	426.75	726.75	-0.01761256 -0.017347833	
		UIC774Hy ashi10 IP aram "Position 41 mys UIC774Hy ashi101Param "Position 42 mys	Braking	250	550	Accelerating	430 433.25		-0.017947893 -0.01783201	FHE TO
		UIC774His ashi101Param"Position 42.mys UIC774His ashi101Param"Position 43.mys	Braking Braking	256.25	566.25	Accelerating Accelerating	433.25	733.25	-0.01783201 -0.017756247	0.010
		UIC 71991washil 1019 aram Position 43, mys UIC 77941washil 1019 aram Position 44, mys	Braking	262.5	562.5	Accelerating	438.75		-0.017756247	0.010
		UIC 714He add IDParam Position 44 mys UIC774He add IDIParam Position 45 mys	Dracing	258.75			433.75			
	45	UIC / 19He ashi 101Param Postion 45, mys UIC 774He ashi 101Param Position 46, mys	Braking	281.25	501.00	Accelerating	446.25		-0.017504237	Church D
	40	UIC 7 NPM ashi101P aram Position 40, mus UIC 774Hv ashi101P aram Position 47, mus	Braking Braking	281.25		Accelerating	449.25		-0.017341322	
	41	UIC 714Hwashill 01Param Position 41 mys	Braking	207.5		Accelerating	443.5	743.5		Civil 10
	43	UIC 7 NH washi 10 Param Position 48 mgs UIC 774Hwashi 10 Param Position 49 mgs	Braking	233.0	533.13	Accelerating	452.75	756	-0.01/076626	
	43	UIC 7 NH washi 101Param Position 43 mus UIC 774H washi 101Param Position 50 mus	Braking	306.25	600 m	Accelerating	458.25	759.25	-0.016892426	Direct 10
	50	UIC 714Hwashill 01Param Position 50, mys	Braking	306.25	606.23	Accelerating	453.25	762.5	-0.016832426	Pior 10
	51	UIC 714He ashi 10 Param Position 51 mps UIC 774He ashi 10 Param Position 52 mps	Braking	312.5	612.1 gan m	Accelerating	465.75	765.75		Dia 10
		UIC 7 NH washi 10 Param Postion 52 mps UIC 774H washi 10 Param Postion 53 mps	Braking	318.11	018.0	Accelerating	465.75			
	54	UIC774Hwashi101Param'Position 54.ms	Braking	331.25	631.25	Accelerating	472.25	772.25	-0.016755321	
	54	UIC 714He ashi101Param Position 55 mis	Braking	331.25		Accelerating	475.5		-0.016755321	Pier 10
	56		Braking	343.75	643.75	Accelerating	478.75	778.75	-0.016792597	Pier 10
		UIC774Hwashi101Param'Position 57.mvs	Braking	350	650	Accelerating	482			Pior 10
	50	UIC774Hwashi101Param*Position 50.ms	Braking	356.25	656.25	Accelerating	405.25	705.25	-0.016797833	Pix 11
		Deck Long, Gap Check-Asial Deck Long, Gap Ch		ong. Gap Check-To						

Figure 55: Longitudinal Deck End Displacement due to Axial Effects Check Worksheet for Multiple Results Files

A	8	c	D	ε	F	G	н	1	J	к
		Check of Longitudinal Relative Displace	ment between Ends	of Decks (End	Rotations)					
_		UIC 774-3Model: UIC 774Hy ashi 101P aram								
	Job Title:	UIC 774-3Model: UIC 774Hy ashi10 Plaram UIC 774Hy ashi101Plaram Position 1> UIC 774Hy ashi101P	san Pastine 12							
		C Projects/J/2504/TrackStructureInteraction								
	Analysis Date:	28/03/2019> 28/03/2019								
	Model Units:	N.m.kg.s,C								
				Track 1			Track 2			
	Analysis ID	Results Filename	Loading Type	Distance from Left End of the Model to the Starting	Distance from Left End of the Model to the Finishing	Loading Type	Distance from Left End of the Model to the Starting	Distance from Left End of the Model to the Finishing	Peak Relative Longitudinal Displacement between Ends of Decks. Positive	Pier Number Location Supporting Decks with
		UIC774Hv ashi101Param/Position 1.mys	Temperature Only			Temperature Only			-1.06514E-05	
		UIC774Hv ashi101Param/Position 1.mys	Braking	6		Accelerating	300	600	0.000491601	Pier 7
	2	UIC774Hv ashi/101P aram/Position 2.mys	Braking	6.25	306.25	Accelerating	303.25	603.25		
		UIC774Hv ashi101Param/Position 3.mys	Braking	12.5	312.5	Accelerating	306.5	606.5		
		UC774Hy ashi101Param/Position 4 mys UC774Hy ashi101Param/Position 5 mys	Braking	18.75		Accelerating	309.75	609.75 613	0.000492027	
		UIC774Hy ashi/01Param/Position 6.mss	Braking	31.25	221.25	Accelerating	316.25	616.25		
	7	UIC774Hy ashi101Param/Position 6.mys	Braking	37.5	337.5	Accelerating	318.25	619.5		Pier 2
		UC770Hz ashi/01Paran/Position 8 mus	Braking	43.75		Accelerating	322.75	622.75	0.000603257	
		UIC774Hy ashi101Param/Position 9.mys	Braking	50	350	Accelerating	326	626	0.000746765	Pier 2
	10	UIC774Hy ashi/101Param/Position 10.mys	Braking	56.25	356.25	Accelerating	329.25	629.25	0.000797724	Pier 2
	1	UIC774Hy ashi101Param/Position 11.mps	Braking	62.5		Accelerating	332.5	632.5	0.000891738	Pier 2
	12	UIC774Hv ashi/101Param/Position 12 mps	Braking	68.75		Accelerating	335.75	635.75	0.000916689	
		UIC774Hv ashi/101Pacam/Position 13.mys	Braking	75		Accelerating	339	635		
	14	UC774Hy ashi101Param/Position 14, mys UC774Hy ashi101Param/Position 15, mys	Braking	8125	381.25	Accelerating	342.25	642.25 645.5	0.000783909	Pier 2
	1	UIC774Hy ashi/01Param/Postion 15 mps	Braking Braking	93.75	307.5	Accelerating	349.5	648.75	0.000636353	Pherz
		UIC774Hy ashi/101Param/Position 17.mm	Braking	100	333.75	Accelerating	340.75	652		
		UIC 774Hy ashi101P at an Postion 17.mgt	Braking	106.25		Accelerating	355.25	655.25	0.000794837	
	19	UIC774Hy ashi101Param/Position 13 mpr	Braking	112.5		Accelerating	358.5	658.5		
	20	UIC774Hy ashi/101Param/Position 20.mvs	Braking	118.75		Accelerating	361.75	661.75		Pier 4
	21		Braking	125		Accelerating	365	665	0.00106717	
	22	UIC774Hv ashi/101Param/Position 22 mus	Braking	131.25	431.25	Accelerating	368.25	660.25		Pier 4
		UIC774Hv ashi/101Param/Position 23.mys	Braking	137.5	437.5	Accelerating	371.5	671.5	0.001042008	Pier 4
		UIC774Hv ashi101Param/Position 24.mys	Braking	143.75	443.75	Accelerating	374.75	674.75	0.001018645	Pier 4
		UIC774Hv ashi/101Param/Position 25.mys	Braking	150		Accelerating	370	678		
		UIC774Hv ashi101Param/Position 26 mys	Braking	156.25		Accelerating	381.25	681.25		
	2/	UIC774Hvashi101Param/Position 27.mys UIC774Hvashi101Param/Position 28.mys	Braking Braking	162.5		Accelerating	384.5	684.5	0.000930103	
_	40	UC774Heashi101Paam/Postion 29 mus	Braking	175	400.71	Accelerating	307.15	691	0.000805822	Derd
		UIC774Hyashi101Paran/Postion 30.mus	Braking	181.25	481.25	Accelerating	394.25	694.25		Plac 7
		UIC774Hyashi101Pacarr/Position 31mus	Braking	187.5		Accelerating	397.5	697.5	0.000915344	
	32	UIC774Hy ashi/101Param/Position 32 mus	Braking	193.75	493.75	Accelerating	400.75	700.75	0.001000933	Pier 7
	33	UIC774Hv ashi/101Param/Position 33.mus	Braking	200	500	Accelerating	404	704	0.001024163	Pier 7
		UIC774Hv ashi/101Param/Position 34.mus	Braking	206.25	506.25	Accelerating	407.25	707.25		
		UIC774Hv ashi/101Param/Position 35.mys	Braking	212.5		Accelerating	410.5	710.5	0.000961466	
	36	UIC774Hv ashi/101Param/Position 36.mys	Braking	218.75	518.75	Accelerating	413.75	713.75	0.00093011	Pier 7
	37	UIC774Hv ashi101Param/Position 37 mys	Braking	225		Accelerating	417	717		
		UIC774Hv ashi101Param/Position 38 mys	Braking	23125		Accelerating	420.25	720.25	0.00091589	
		UC774Hv ashi101Pacan/Postion 39.mys UC774Hv ashi101Pacan/Postion 40.mys	Braking Braking	237.5	537.5	Accelerating	423.5	723.5		
_		UIC774Hy ashi101Patan Poston 40 myt	Braking	293.73		Accelerating	430	730		
		UIC 774Hy ashi101P at an Position 42 mut	Braking	256.25	000.05	Accelerating	430.25	733.25	0.000336752	
	43	UIC774Hyashi101Paam/Postion 43 mus	Braking	282.5	562.5	Accelerating	436.5	736.5	0.00096102	
		UIC774Hy ashi101Param/Position 44.mus	Braking	268.75		Accelerating	439.75	739.75	0.000999631	Pier 10
	45	UIC774Hy ashi/101Pacam/Position 45 mut	Braking	275	575	Accelerating	443	743	0.001024825	Pier 10
	46	UIC774Hv ashi/101Param/Position 46.mus	Braking	28125	581.25	Accelerating	446.25	746.25	0.001004322	Pier 10
		UIC774Hvashi101Param/Position 47.mys	Braking	287.5	587.5	Accelerating	449.5	749.5		
		UIC774Hv ashi101Param/Position 48.mys	Braking	293.75		Accelerating	452.75	752.75	0.000992239	Pier 7
	43	UIC774Hv ashi101Param/Position 43 mys	Braking	300		Accelerating	456	756	0.000964286	Pler 7
	50	UC774Hv ashi101Param/Position 50 mys UC774Hv ashi101Param/Position 51 mys	Braking	306.25	606.25	Accelerating	453.25	759.25	0.000937144	
		UC774Hvashi101Param/Position 51.mst UC774Hvashi101Param/Position 52.mst	Braking Braking	312.5	612.5	Accelerating	462.5	762.5 765.75	0.000945939 0.0009532	
_		UIC774Hy ashift/thraam Postion 52 mys UIC774Hy ashift/thraam Postion 53 mys	Braking	318.71		Accelerating	465.05	765.75		
	20	UIC 7 Here as a full of Param Position 53 mpt	Braking	33125	804.06	Accelerating	403	772.25	0.000954295	Play 10
		UIC774Hy ashi101Param/Position 55 mut	Braking	337.5		Accelerating	475.5	775.5	0.0009539	
	96		Braking	343.75		Accelerating	478.75	778.75	0.000952197	
	57	UIC774Hy ashi/101Param/Position 57 mus	Braking	350	650	Accelerating	482	782	0.000948673	Piec 10
		UIC774Hv ashi101Param/Position 58 mus	Braking	356.25		Accelerating	485.25	785.25	0.000944291	

Figure 56: Longitudinal Deck End Displacement due to End Rotation Effects Check Worksheet for Multiple Results Files

A	B	C	0	E	1	G	н		J	K
		Check of Longitudinal Relative Displacer	nent between Ends	of Decks (Tota	Effects)					
-										
	Job Title:	UIC 774-3 Model: UIC 774Hv ashi/101Param								
Acalur	ir Filename:	UC774HvashI01Paran/Position 1> UIC774HvashI101Pa	ran/Postion 101							
		C:IPtojectel/ft2504/TrackStructureInteraction								
0.0	asheric Date:	28/03/2019> 28/03/2019								
	Model Units:									
	Picolei Olins.	Nonoigsto								
				Track 1		_	Track 2			
_				Distance from	Distance from		Distance from	Distance from	Peak Relative	Pier Numbe
				Distance from			Distance from	Left End of the		
A	malysis ID	Results Filename	Loading Type	Left End of the	Left End of the	Loading Type	Left End of the		Longitudinal	Location
				Model to the	Model to the		Model to the	Model to the	Displacement between	Supportin
				Starting	Finishing		Starting	Finishing	Ends of Decks. Positive	
	1	UC774Hv ashi101Param/Position 1.mys	Temperature Only			Temperature Only			-0.014516705	
	1	UC774Hv ashi/0/Param/Position 1.mys	Braking		300	Accelerating	300	600		Pier 10
	2	UC774Hv ashif01Param/Position 2.mys	Braking	6.25	306.25	Accelerating	303.25	603.25	-0.014440	Pier 10
	3	UC774Hvashil01Param/Position 3.mss	Braking	12.5	312.5	Accelerating	306.5		-0.01444484	
	4	UC774Hv ashif01Param/Position-4.mys	Braking	18.75	318.75	Accelerating	309.75		-0.01444735	
	5	UC774Hvashif01Param/Position5.mut	Braking	25	325	Accelerating	313	613	-0.0144514	1 Pier 10
	6	UC774Hvashil01Param/Position 6 mus	Braking	31.25	331.25	Accelerating	316.25		-0.0144553	Pier 10
	7	UC774HyachE01ParamPosition 7 mus	Braking	37.5	337.5	Acceleration	319.5	619.5	-0.0144613	Pier 10
		UC774Hvashi101Param/Position/8.mss	Braking	43.75	343.75	Accelerating	322.75	622.75	-0.0344678	Der Ti
- 1		UCT74Hvashi10ParamPosition3.mvs	Braking	50	360	Accelerating	326	626	-0.01447753	Rev T
- 1	10	UC1714Hy ashift01Param Position 10.mys	Braking	56.25		Accelerating	329.25		-0.01449524	
		UC 174Pix ashift Param Position 10 mys UC 174Pix ashift Param Position 11 mvs	Braking	62.1		Accelerating	323.25		-0.01453024	
- 1 -	11	UCT74Hv ashifU Param Position 12 mys		62.1	362.5		335.75		-0.01453700	
	12	UIC 774Phy ashift01P at am Position 12 mys	Braking	68.75	368.75	Accelerating			-0.01453700	Pier 10
	13	UIC774He ashi101Param/Position 13.mys	Braking	8125		Accelerating	339	639 642.25		
	94	UIC774Hv ashi101Param/Position 14 mys	Braking			Accelerating				7 Pier 10
	15	UC774Hv ashi101Param/Position 15 mys	Braking	87.5		Accelerating	345.5	645.5	-0.014603325	
	16	UC774Hv ashil101Param/Position 16.mys	Braking	93.75		Accelerating	348.75		-0.014626683	
	17		Braking	100	400	Accelerating	352	652	-0.014651455	5 Pier 10
	18	UC774Hvashif01Param/Position 18 mvs	Braking	106.25	406.25	Accelerating	355.25	655.25	-0.01469760	1 Pier 10
	19	UC774Hvashil01Param/Position 13.mvs	Braking	112.5	412.5	Accelerating	358.5	658.5	-0.0147383	Pier 10
	20	LIC774HvadsE01Param/Position/20 mys	Braking	18.75	4875	Accelerating	361.75	66175	-0.01477545	Pier10
	21	UIC774Hvashif01Param/Position 21 mvs	Braking	125	429	Accelerating	365	665	-0.01488285	Dier 7
		UC774HvashII01Param/Position 22 mvs	Braking	131.25	431.26	Accelerating	368.25	668.25	-0.015064	Der 7
	21	UCT74Hvashi10ParamPosition 23.mvs	Braking	137.5		Accelerating	3715		-0.01527615	
	23	UCT70Hy ashift() Param Position 23 mys	Braking	107.0		Accelerating	374.75	674.75	-0.01550763	10-7
_	25	UCT74Hy ashift0 Param Position 25 mis	Braking	150		Accelerating	370		-0.01572494	Contract of the second se
_	25	UC1714Hy ashill/Param Position 25 mys	Braking	156.25		Accelerating	381.25		-0.01587563	Pier r
_										
		UIC 774Hv ashi101P aram Position 27 mys	Braking	162.5	462.5	Accelerating	384.5	684.5	-0.01539181	2 Pier i
	28		Braking	168.75	468.75	Accelerating	387.75	687.75	-0.01608304	Pier 7
	29	UIC774Hv ashi101Param/Position 23 mys	Braking	175	475	Accelerating	391	691	-0.016179056	
		UIC774Hv ashif01Param/Position 30.mys	Braking	181.25	481.25	Accelerating	394.25			
		UIC774Hv ashif01Param/Position 31.mys	Braking	187.5		Accelerating	397.5			
	32	UC774Hvashil01Param/Position-32.mvs	Braking	193.75	493.75	Accelerating	400.75	700.75	-0.01582445	Pier 10
	33	UC774Hvashif01Param/Position 33.mvs	Braking	200	500	Accelerating	404		-0.01600718	Pier 10
	34	UIC774Hv ashif01Param/Position 34 mvs	Braking	206.25	506.25	Accelerating	407.25	707.25	-0.01621268	1 Pier 10
	35	UC774HvashE01Param/Position 35 mvs	Braking	212.5	512.5	Accelerating	410.5	710.5	-0.01642571	Pier 10
	36	UC774HvashII01ParamPosition-36.mvs	Braking	218.75	518.75	Accelerating	413.75	713.75	-0.01664567	Pier 10
	12	UCT74Hvashi101ParamPosition-37.mvs	Braking	225		Accelerating	412	717	-0.01603289	
- 1	38	UC174Hy ashift01P aram Position 38 mys	Braking	231.25		Accelerating	420.25	720.25	-0.01696960	Der T
	30	UCT74Hv ashift0 Param Position 30.mys	Braking	231.2	631.23	Accelerating	423.5	723.5	-0.01707008	Ren TO
- 1	33	UC774Hy ashi101P aram Position 30 mys	Braking	24375	537.5	Accelerating	426.75		-0.01715094	0.00
			orwang .		543.15	Accelerating				
	41	UIC774He ashii 101Param Position 41.mys	Braking	250		Accelerating	430	730	-0.017220013	
	42	UC774Hv ashi101Param/Position-42.mys	Braking	256.25		Accelerating	433.25	733.25	-0.017036363	Pier 10
	43	UIC774Hv ashi101Param/Position-43.mys	Braking	262.5		Accelerating	436.5		-0.0168431	5 Mier 10
	44	UIC774Hv ashi101Param/Position-44 mys	Braking	268.75	568.75	Accelerating	439.75		-0.016632424	Pier 10
	45		Braking	275	575	Accelerating	443	743	-0.01647941	Pier 10
	46	UC774Hvashil01Param/Position-46.mys	Braking	281.25	581.25	Accelerating	446.25		-0.01633	
	47	UC774HvadsE01Param/Position-47 mus	Braking	287.5	587.5	Accelerating	449.5	749.5	-0.016236208	Pier 10
	48	UIC774Hv ashE01Param/Position-48 must	Braking	253.75		Accelerating	452.75	752.75	-0.01613343	
	43		Braking	300	600	Accelerating	456	756	-0.01603753	Per 1
- 1		UC174Hvashi101ParamPosition50.mvs	Braking	306.25	606.25	Accelerating	453.25	759.25	-0.07535528	Der 10
- 1	50	UC778Hyashi10Paran Position 51 mus	Braking	312.5	000.23	Accelerating	462.5	762.5	-0.01508316	0
	51	UC 774Plv ashift0 Param Position 51 mys		312.5	612.5	Accelerating	462.5	762.5	-0.01582372	Concerned and Co
-	52		Braking							
		UIC 774Hv ashi101Param/Position 53 mys	Braking	325		Accelerating	469			
	54	UIC 774Hv ashi101P aram Position 54 mys	Braking	331.25		Accelerating	472.25			
	55	UC774He ashi101ParamPosition55.mys	Braking	337.5	637.5	Accelerating	475.5	775.5	-0.015010230	Pier 10
	56	UIC774Hv ashi101Param/Position 56 mys	Braking	343.75		Accelerating	478.75		-0.015940-	
	57	UIC774Hv ashi/101P at an 'Position 57.mys	Braking	350		Accelerating	482		-0.015856152	
		UC774Hy ashi/01Param/Position 58 must	Braking	356.25	000 000	Accelerating	485.25	785.25	-0.01585354	Dim 10

Figure 57: Longitudinal Deck End Displacement due to Total Effects Check Worksheet for Multiple Results Files

A	В	С	0	ε	F	G	н	1	J	K
_		Check of Vertical Relative Displacement betw	veen Ends of Der	k.						
-		check of vertical kelative Displacement bet	veen enus or per	<u>N3</u>						
	Job Titles	UIC 774-3 Model: UIC 774Hs ashi101Param								
A.	alusia Edename:	UIC774Hvashilt01Param/Position 1> UIC774Hvashilt01Param/P	nakion 101							
	Model Directory	C.Projectal/12504/TrackStructureInteraction	014041101							
	Analusis Date:	08/06/2017> 08/06/2017								
	Model Units:	NmkasC								
		nono guave								
				Track 1			Track 2			
- F									Peak Belative Vertical	
				Distance from	Distance from		Distance from	Distance from	Displacement between	
				Left End of the	Left End of the		Left End of the	Left End of the	Ends of Decks, Positive	Pier Nu
	Analysis ID	Besults Filename	Loading Type	Model to the	Model to the	Loading Type	Model to the	Model to the	= Nest dock / abutment	Suppo
				Starting	Finishing		Starting	Finishing	higher than previous,	Decks wit
				Position of the Loading (m)	Position of the Loading (m)		Position of the Loading (m)	Position of the Loading (m)	Negative = Next deck /	Displace
				Loading (m)	Loading (m)		Loading (m)	Loading (m)	abutment lower than	
	1	UIC774Hvashil01Param/Position 1.mps	Temperature Only			Temperature Only			-8.73504E-08	FHAbutner
	1	UIC774Hwashil101Pacam/Position 1 mus	Braking	0	300	Accelerating	300	600	-7.25557E-07	LH Abutmer
	2	UIC774Hwashil101Param/Position 2.mus	Braking	6.25	306.25	Accelerating	303.25	603.25	-9.2416E-07	LH Abutmer
	3	LIC774Heashil01Param/Position 3.mus	Braking	12.5	312.5	Accelerating	306.5	606.5	-10063E-06	LH Abutmae
	4	UIC774Hwashi101Param/Position 4.mus	Braking	18.75	318.75	Accelerating	309.75	609.75	-9.9023E-07	LH Abutmer
	5	UIC774Hwashi101Param/Position 5.mus	Braking	25	325	Accelerating	313	613	-9.06053E-07	LH Abumer
	6	UIC774Heashill0IParam/Position 6.mus	Braking	31.25	331.25	Accelerating	316.25	616.25	-7.93977E-07	LH Abutmer
	7	LIC774Hyashil0/Param/Position 7 mus	Braking	37.5	337.5	Accelerating	319.5	619.5	-6.92967E-07	LH Abutmen
	8	UIC774Hvashi101Param/Position 8.mvs	Braking	43.75	343.75	Accelerating	322.75	622.75	-6.2848E-07	LH Abumer
	9	UIC774Heashil101Param/Position 3.mus	Braking	50	350	Accelerating	326	626	3.85909E-07	Pier 2
	10	UIC774Hwashil101Param/Position 10.mys	Braking	56.25	356.25	Accelerating	329.25	629.25	7.79871E-07	RHAbutmer
	11	UIC774Hyashi101Param/Position 11.mvs	Braking	62.5	362.5	Accelerating	332.5	632.5	7.79555E-07	RHAbutmer
	12	UIC774Hvashil101Param/Position 12.mys	Braking	68.75	368.75	Accelerating	335.75	635.75	7.79334E-07	RHAbutmer
	13	UIC774Hwashi101Param/Position 13.mvs	Braking	75	375	Accelerating	339	633	7.79108E-07	RHAbutmer
	14	UIC774Hv ashi101P aram Position 14 mys	Braking	81.25	381.25	Accelerating	342.25	642.25		RHAbutmer
	15	UIC774Hvashil101Param/Position 15.mys	Braking	87.5	387.5	Accelerating	345.5	645.5		RHAbutmer
	16	LIC774Hvashil101Param/Position 16.mys	Braking	\$3.75	393.75	Accelerating	348.75	648.75	7.78307E-07	RHAbutmer
	17	UIC774Heashi101Param/Position 17.mys	Braking	100	400	Accelerating	352	652	7.79438E-07	Pier 4
	18	UIC774Hvashil101Param/Position 18.mps	Braking	106.25	406.25	Accelerating	355.25	655.25	7.77573E-07	RHAbutmer
	19	LIC774Hvashi101Param/Position 13.mys	Braking	112.5		Accelerating	358.5	658.5		RHAbutmer
	20	UIC774Hwashil101Param/Position 20.mus	Braking	18.75		Accelerating	361.75	661.75	7.76762E-07	RHAbutmer
	21	UIC774Hwashil101Param/Position 21.mus	Braking	125	425	Accelerating	365	665	7.76375E-07	RHAbutmen
		UIC774He ashi101P aram/Position 22 mys	Braking	131.25			368.25	668.25	7.7597E-07	RHAbutmer
		UIC774Hwashil101Param/Position 23.mys	Braking	137.5	437.5	Accelerating	3715	671.5	7.75548E-07	RHAbutmer
		UIC774Hwashi101Param/Position 24.mys	Braking	143.75		Accelerating	374.75	674.75		RHAbutmer
	25	LIC774Heashil01Param/Position 25.mys	Braking	150	450	Accelerating	378	678	7.74649E-07	FIHAbutmer
	26	UIC774Hwashil101Param/Position 26.mys	Braking	158.25	458.25	Accelerating	381.25	681.25	7.74203E-07	RHAbutmer
	27	UIC774Hvashi101Param/Position 27.mys	Braking	162.5	462.5	Accelerating	304.5	684.5	7.73742E-07	RHAbutmer
	28	UIC774Hvashil101Param/Position 28.mys	Braking	168.75	468.75	Accelerating	387.75	687.75	7.7327E-07	RHAbutmer
		UIC774Hwashi101Param/Position 23.mys	Braking	175	475	Accelerating	391	691	8.35026E-07	Pier7
	30	UIC774Heashi101Param Position 30.mys	Braking	191.25	481.25	Accelerating	394.25	694.25	7.71751E-07	RHAbutmer
-	31	UIC774Hv ashi101Param/Position 31.mys	Braking	187.5			397.5	697.5	7.70887E-07	RHAbutmer
	32	UIC774Hvashi101Param/Position 32.mys	Braking	193.75	493.75	Accelerating	400.75	700.75	7.70045E-07	RHAbutmer
		UIC774Heashi101Param/Position 33.mys	Braking	200		Accelerating	404	704		RHAbutmer
	34	UIC774Hvashil101Param/Position 34.mys	Braking	206.25	506.25	Accelerating	407.25	707.25	7.68525E-07	RHAbutmer
	35	UIC774Hvashi101Param/Position 35.mys	Braking	212.5		Accelerating	410.5	710.5	7.67773E-07	RHAbutmer
		UIC774Hvashi101Param/Position 36.mys	Braking	218.75	518.75	Accelerating	413.75	713.75	7.67023E-07	RHAbutmen
	37	UIC774Hwashil101Param/Position 37.mys	Braking	225	525	Accelerating	417	717		RHAbutmer
	38		Braking	231.25	531.25	Accelerating	420.25	720.25		RHAbutmer
	39	UIC774Hvashil101Param/Position 33.mys	Braking	237.5	537.5	Accelerating	423.5	723.5	7.64466E-07	RHAbutmer
	40	UIC774Hvashi101Param/Position 40.mys	Braking	243.75	543.75	Accelerating	426.75	726.75		RHAbutmen
	41	LIC774Heashil01Param/Position 41.mps	Braking	250	550	Accelerating	430	730	8.30904E-07	
	42	UIC774Hvashil101Param/Position 42.mys	Braking	258.25	558.25	Accelerating	433.25	733.25	7.65606E-07	
		UIC774Hwashil101Param/Position 43.mys	Braking	262.5	562.5	Accelerating	436.5	736.5		RHAbutmer
		UIC774Hv ashi101P aram/Position 44.mys	Braking	268.75	568.75	Accelerating	439.75	739.75	7.87265E-07	
		UIC774Hwashil101Param/Position 45.mys	Braking	275	575	Accelerating	443	743	7.92204E-07	RHAbutmer
	46		Braking	281.25	581.25	Accelerating	446.25	746.25		FHAbutmen
	47	UIC774Hvashil101Param/Position 47.mys	Braking	287.5	587.5	Accelerating	449.5	749.5	-7.56552E-07	LH Abutmer
	48	UIC774Hwashi101Param/Position 48.mys	Braking	293.75	593.75	Accelerating	452.75	752.75	-7.56736E-07	LH Abutmen
	49	UIC774Heashi101Param/Position 49.mus	Braking	300	600	Acceleration	456	756	-7.34005E-07	LHAbstman
	50	UIC774Hwashil101Param/Position 50.mus	Braking	306.25	606.25	Accelerating	459.25	759.25	7.16688E-07	RHAbutmen
	51	UIC774Hwashi101Param'Position 51.mvs	Braking	312.5	612.5	Accelerating	462.5	762.5	8.65324E-07	RHAbutmen
	52	UIC774Heashil101Param/Position 52.mus	Braking	318.75	618.75	Accelerating	465.75	765.75	115794E-06	FHAbutmen
	53	UIC774Hwashil101Param/Position 53.mus	Braking	325	625	Accelerating	469	763	153266E-06	RHAbutmen
	54	UIC774Hwashi101Param'Position 54.mvs	Braking	331.25	631.25	Accelerating	472.25	772.25	1675TE-06	RHAbutmen
	55	UIC774Hv ashi101Param/Position 55 mus	Braking	337.5	637.5	Accelerating	475.5	775.5	1675-06	FHAbutmen
			k Long. Gap Check-Tota				100.00	220.25		Inun

Figure 58: Vertical Deck End Displacement Check Worksheet for Multiple Results Files

A	8	C	D	Ε	F	G	н	1	J	К	L
		Check of Longitudinal Reactions									
_											
		UIC 774-3 Model: UIC 774Hy ashi 101Param									
An	alysis hilename:	UIC774His ashi101Param/Position 1> UIC774His ashi101Param/Po	sition 101								
	Model Directory:	C:IProjects/J12504/TrackStructureInteraction 28/03/2019> 28/03/2019									
	Analysis Date: Model Units:										
	Model Units:	NUMUKQUSUU									
				Track 1			Track 2				
- 1				Distance from	Distance from		Distance from	Distance from			
- 1				Left End of the	Left End of the		Left End of the	Left End of the	Peak	Abutment / Pier	
	Analysis ID	Results Filename	Loading Type	Model to the	Model to the	Loading Type	Model to the	Model to the	Longitudinal	Number with	
				Starting	Finishing		Starting	Finishing	Reaction (N)	Peak Reaction	
- 1		UIC774Headbil01Param Position 1 mos	Temperature Only			Temperature Only			300463.4131	Pier5	
		UIC774Hwashi101Param/Position 1.mus	Braking	0	300	Appelerating	300	600	249128 7349	Pier 5	
	2	UIC774Hwashi101Param'Position 2.mvs	Braking	6.25	306.25	Accelerating	303.25	603.25	244351.4852	Pier5	
	3	UIC774Hy ashi/101Param Position 3 mus	Breking	12.5	312.5	Appelerating	306.5	606.5	239183.3946	Pier5	
		UIC774Hwashi/101Param/Position 4.mus	Braking	18.75		Accelerating	303.75	603.75	-268712.8426		
	6	UIC774Hwashi101Param/Position 5.mys	Braking	25		Accelerating	313		-306729.9616		
	e	UIC774Hwashil101Param'Position 6.mys	Braking	31.25	33125	Appelerating	316.25		-331727.7563	Pier1	
		UIC774Hwashi101Param/Position 7.mys	Braking	37.5	337.5	Accelerating	319.5		-350305.3031		
		UIC774Hwashi101Param'Position 8.mps	Braking	43.75	343.75	Accelerating	322.75	622.75	-370518.4442		
	9	UIC774He adul101Param/Position 3.mys	Braking	50	350	Accelerating	326	626	-332065.1676	Pier1	
	10	UIC774Hwashi101Param/Position 10.mys	Braking	56.25	356.25	Accelerating	329.25	629.25	-395055.8487	Pier1	
		UIC774Heashi101Param/Position 11.mps	Braking	62.5	362.5	Accelerating	332.5		-395802.4265	Pier1	
		UIC774His ashi/101Param/Position 12 mys	Braking	68.75	368.75	Accelerating	335.75		-450938.8919		
	13	UIC774Hirashi101Param/Position 13.mys	Braking	75		Accelerating	339	639	-527890.0365	Plet 3	
	н	UIC774He adul101Param/Position 14.mys UIC774He adul101Param/Position 15.mys	Braking	81.25 87.5	38121	Accelerating	342.25		-591623.6377	Plei 3	
	15	UIC / /Htwashil/UParam/Position 15 mys UIC774Hwashil/0/Param/Position 16 mys	Braking	93.75	387.5	Accelerating Accelerating	345.5	645.5	-649542.5307 -707463.8815	Pier 3	
		UIC 774Headed 101Param Position 10.mys	Braking Braking	53.15	333.75	Accelerating	340.75	652	-763144.9319	Piel 3	
	10	UIC774Hwashi101Param/Position 18 mus	Braking	106.25		Accelerating	355.25	655.25	-786742.7662	Plet 3	
	10	UIC / remease IOParam Position 10.mys	Braking	106.25	400.23	Accelerating	358.5	658.5	-804821792	Pier 3	
	10	UIC774Headed101Param/Position 20.mos	Braking	110.71	410.1	Accelerating	36175	661.75	-010003.335	Piero 3	
	21	UIC774Hwashi101Param/Position 21.mus	Braking	125	424	Accelerating	365		-832402.889	Plat 3	
	21	UIC774Hwashi101Param Position 22 mvs	Braking	131.25	43125	Accelerating	368.25	668.25	-848416.2616		
	23	UIC774He add/01Param/Position 23.mus	Breking	137.5	437.5	Appelerating	3715		-852138.4368		
	24	UIC774Hwashi101Param'Position 24 mus	Braking	143.75		Accelerating	374.75	674.75	-871871.5242	Pier 3	
	25	UIC774Hwashi101Param*Position 25 mvs	Braking	150		Accelerating	378	678	-880195.3963	Pier3	
	28	UIC774He add/101Pacam/Position 28 must	Breking	156.25	456.25	Accelerating	381.25	681.25	-894155.9535	Pier 3	
	27	UIC774Hwashil101Param/Position 27.mys	Braking	162.5	462.5	Accelerating	384.5	684.5	-908728.3566	Pier 3	
		UIC774Hwashil101Param*Position 28 mys	Braking	168.75	468.75	5 Accelerating	387.75		-922969.8157	Pier 3	
		UIC774Hwashi/101Param/Position 29.mys	Braking	175	475	Accelerating	391	691	-935591.3728		
		UIC774Hwashi101Param/Position 30.mys	Braking	161.25		5 Accelerating	394.25		-933465.5555		
		UIC774Hwashi101Param'Position 31.mys	Braking	187.5	487.5	5 Accelerating	397.5		-930168.3515		
	32	UIC774Hwashi101Param/Position 32.mys	Braking	193.75	493.75	Accelerating	400.75	700.75	-324013.584		
		UIC774Hirashi101Param/Position 33.mys	Braking	200	500	Accelerating	404		-925393.8574		
_		UIC774Heashil01Param/Position 34.mys	Braking	206.25	506.25	Accelerating	407.25		-930937 2558		
	35	UIC774Hirashi101Param/Position 35.mys	Braking	212.5	512.5	Accelerating	410.5		-938928.7856	Plet 3	
	36	UIC774Hwashil101Param/Position 36.mps	Braking	218.75	510.75	Accelerating	413.75	713.75	-947623.5643	Pier 3	
	37	UIC774Headel101Param/Position 37 mys UIC774Headel101Param/Position 38 mys	Braking	225	525	Accelerating	417 420.25		-957989.2693 -971371.8014	mer5	
		UIC / AHwashiTUParam Position 38.mys UIC774HwashiT01Param Position 39.mys	Braking	231.25	53125	Accelerating Accelerating	420.25		-9/13/1.8014		
	30	UIC 174Hv ashi101Param Position 30.mys UIC 774Hv ashi101Param Position 40.mys	Braking Braking	243.75	537.5	5 Accelerating 5 Accelerating	423.5		-364833.0257 -1000473.476	Der	
	40	UIC774Hwashi101Param/Position 40.mys	Braking	243.1	543.75	Accelerating	430	730	-1035214.782	Dure	
	41	UIC / rene ashi DiParam Position 41 mys	Braking	256.25	300	Accelerating	430.25	733.25	-1051741,252	Piero D	
	42	UIC / (4Phi ashi UIParam Position 42 mps UIC 774His ashi 101Param Position 43 mus	Braking	262.5	990.23	Accelerating	433.25		-1051741252	Date	
	4.	UIC774Hwashi10Param/Position 43.mps	Braking	268.75	568.7	Accelerating	439.75		-106/7397.361		
	44	UIC774Headel101Param/Position 45.mvs	Braking	200.10		5 Accelerating	443		-1103765.694	Dec	
	4	UIC774Headed101Param/Position 46.mus	Braking	201.25	58125	5 Accelerating	446.25	746.25	-1132009.535	Pierß	
	47	UIC774Hwashi101Param Position 47.mvs	Braking	287.5	587.5	Accelerating	449.5	743.5	-1172583.556	Pierß	
		UIC774He ashi/101Param Position 48.mus	Breking	293.75		Appelerating	452.75		-1211179.57		
	49	UIC774Hwash/101Param/Position 43 mus	Braking	300	600	Appelerating	456	756	-1245385.721	Pier8	
	50	UIC774Hwashil101Param'Position 50.mvs	Braking	306.25	606.25	Appelerating	453.25	758.25	-1274506.787	Pier8	
		UIC774Hearbil101Param Position 51.mus	Braking	312.5	612.5	Appelerating	462.5		-1300387.837		
		UIC774Hwadh/101Param/Position 52 mut	Braking	318.75	618.75	Accelerating	465.75	765.75	-1324399.272		
		UIC774Hwashi101Param'Position 53 mvs	Braking	325	625	Accelerating	463	769	-1346310.158		
	54	UIC774Hwashi/101Param/Position 54 mys	Braking	331.25	63125	Accelerating	472.25	772.25	-1358221.696	Pier 8	
	55	UIC774Hwashi101Param'Position 55.mus	Braking	337.5	637.5	5 Accelerating	475.5	775.5	-1369262.069	Pier 8	
	56	UIC774Hwashil101Param'Position 56.mys	Braking	343.75	643.75	5 Accelerating	478.75	778.75	-1372416.668	Pier 8	
	57	UIC774Hy ashil 101Param Position 57.mps	Braking	350	650	Accelerating	482	782	-1374216.494	Pier 8	
		UIC774Hwashil101Param'Position 58 mus	Braking	356.25		5 Accelerating	485.25	785.25	-1369466.535		



		0	D	E	r .	6	н			к	L	н	N	0	P	
1		Check of Axial Rail Stress														
and and a first	ab Title:	UIC TT4-3 Madeb UIC TT4NoorbitWIP or on UIC 774Hoorbit971P or on "Parities 1-+, UIC 774Hoorbit971P or on	Paulities Md													
Madel Dis	addary:	0.1Praject/U/125040Track/StructureInteraction	Parties In													
Hada	al Unite: 1	Keder/														
				Treek 1		_	Treek 2									
_	_			Dirtence from	Dirtance from		Distance from	Dirtence from	Peak Hart	Treak Humber	Distance from		Park Hart	Track Humber	Dirtesco fras	•
	- 1				Laft Ead of the		Laft End of the	Laft End of the	Tearile Aziel	with Poek	Laft End of	Description of	Camprogries	with Pook	Laft End of	Barro
da.ely	parie ID	Receilte Fileneme	Looding Type	Hadel to the	Hadal to the	Lording Type	Hadel to the	Hadal to the		Hart Tearily	Structure for	pash Incotion		Hart	Structure fai	
	- 1			Parities of the	Paritian of the		Parities of the	Parities of the	(MP+)	Steam	Tearile Streer		Ball (MPa)	Camprassies Steam	Camprosries.	
		UIGTTNHwarhi101P or on "Parities Unity	Temperature Only			Temperature Only			34,50472655		1 (2)	MRNin Deck 3	-46.04217925			25 AHAH
	- 0	UIC774Hunshilt91Param "Paritian Surge	Braking		20	Accelerating	244	600	26.46256724		10	Wikkis Dunk 2	-45.66152110		4 2	25 RHAL
		UICT74Hurahi1991Foron "Parition 2 myr UICT74Hurahi1991Foron "Parition 3 myr	De sking Braking	6.25	284.2	Accoluration	293.25	607.25 646.5	24,45129535 34,45422444		1 10	Vikin Duck 3 Vikin Duck 3	-45.69525912 -45.69325629		1 2	23 AHA5-0
	- 2	U07749 pahilth Foran Parities 4 my	Desking	91.75			101.5	644.75	16 45667334			Stable Deck 3	-45.6550004		1 1	California D
		UC274HumbilthTP areas "Parities & ever	Braking	25	321	Antelection	212	612	26.64914624		10	Within Durch 2	-45.64415174		2 3	24 WHAND
		URO 774Bhurachi H99Bhoronn "Paritian 6 Javyy	Draking	21.25			211.25	616.25	34,40192692	1	101	WHILE Duck 2	-45.64752267		a >	Ce VIALD
		UICT7Huashi101Feren "Parities Taxy UICT7Huashi101Feren "Parities Taxy	Braking	0.75	337.	Accelerating	319.5	619.8	36.40288652 36.4244235		10	Vikhis Duck 3 Vikhis Duck 2	-47.1774907		1	Se VisioD
	- 2	UIC / Missarls/1919 or on "Partian Lavy" UIC / Missarls/1919 or on "Paritien 1 mor	Braking				322.19	622.05	35.4244235		10	Within Duck 2	-0.14(1097)		1 (20 WHAND
1	10	UR0774B4urachi2951P or one "Pracition 59 years	Draking	\$4.25	254.21	Accelerating	229.25	629,25	36,36644359		0	While Dusk 2	-46.57997465		a i	De VOLLO
			Braking										-47.62499402		a	Telson D
				41.75	268.2	Assolution	225.75	635.75	26.3628928		10	Vikiu Duck 2	-49.32926672		3 1	De WALLD
1	- 2	ISOTTHuashi101Foron "Farition IS may ISOTTHuashi101Foron "Farition Manage	Braking Braking	1938	2012	Accolurations	225	639	34.3484277 34.32793464		0	VIRNin Duck 3 ViRNin Duck 2	-45,11500-856 -50,45270481		a 1	ne Plard
	120	USO T74Husehilt91Foron "Facilian IS Avv		47.5			345.5	645.5	34.34792995		10	Within Duck 3	-51,71420624			en statio D
1			Braking	92.79			242.75	648.75	26.22799116		10	Within Duck 2	-\$2.94319943			
		UC774Huahil991Foron "Parition 17.n.yz	Draking	190.25		Accolutating	352	152	36,2666283		0	WHINE Deck 2	-53.05179957		3	se vosia D
1		UCT704 and UDTP or on "Parities States"	Braking Draking	195.25	40.2	Assolution	255.25	658.25	24.33642838		9	Vikhis Duck 2 Vikhis Duck 2	-54,90310154			Tel Viskin D
	24	UIC774Huarhi101Peran "Parities 28 mor	Braking	111.75	411.7	Accelerating	361.75	661.75	36.70621211		6	Within Duck 3	-51.12345124		2 1	Te Vitis D
			Draking	95							0	WRATE Duck 2				
		UICTTHLoads1991Peren "Parities 22 myr UICTTHLoads1991Peren "Parities 23 myr	Braking	0125		Accolurations	355.25	668.25	34,47934887		9	Within Deck 3 Within Deck 2	-65,1326,0595		5 5	ne stable.D
		US77NHwahi101Peren "Parities 23 nov US77NHwahi101Peren "Parities 24 nov	Braking	1073	437.	Accoluteting	374.75	674.75	35,50014173			StitusDuck3	-64,20204514		a :	19 Piert
	28	UIC774Harahil991Paran "Paritian 25 myr	Prehing	150			278	678	25.12525825		12	White Duck 2	-45.52245245		3	IS Plar 7
			Braking	194.25			39125	611.25	35.89990113	1	10		-\$5.51219919			
	27	UIC776Harahi1991Paran "Paritian 22 mov	Braking	912.5	462.	Assolutions	224.6	684.5	25.6509977		10	Windust 2	-67.42290000		4 1	De Within D
		UG774Howhild/IP even "Parities 21.myr	Braking Braking	164.75	41.2	Accoluration	397.15	647,75	26.21425701			Vikhis Duck 3 Vikhis Duck 2	-68.4220149		9 !	Te Visio D
		UICT7NHwahi1991Foron /Facilian 28. Agr	Draking	911.25 977.8	491.27	Assalutation	29425	694,25 697,5	24.22000592			WHILE Duck 2	-10.22115427		1	De Makin D
				117.5				647.5			10		-67.84950292		2 i	Te vistin D
	22	UI0774Harahilth1Peron/Parities32.mpr	Draking Braking	190.75 299	452.2	Accolumating	499.75	744.75	34.21407744		0	Vikhis Duck 3 Vikhis Duck 3	-67.19216772		1	15 Plue 1
	- 22	UCT70Humbil00Feren "Parities 33.exy UCT70Humbil00Feren "Parities 34.exy	Draking	204.25	50	Accelerating	497.25	704 Te7.25	24.25242544				-68.29017068		a :	en vista D
	290	UKC774Hurschill/191Foron "Parities 35 mor	Braking	292.8	512.	Accelerating	49.5	718.5	34.20495395		6	Within Deck 3	-47.94713449		2 2	54 944 50
				241.75			40.75	710.75	26.56249992				-69.1442224			
	37	UICTIVHushill91P or on "Parities 37 mor	Braking	225	52	Accolutation	417	117	34.80149222		0	WHNIs Deck 3	-14.0101		2 2	St Play St
	- 21	UIC 774Hanashi H91P or on "Parisian 28 aryu UIC 774Hanashi H91P or on "Parisian 35 aryu	Draking Braking	224.25	621.2	Accolurations	429.25	724.25	24.0476996			Vikin Duck 2 Vikin Duck 3	-78.00342711		3 3	an Webber
			Braking	240.75			426.75	726.75	21.00147757		1	Vibbis Desk 2	-72,49279,715			
	- 40	UIC774Hushilth1Foron 7Farition4Losy		259			428	730	48,39669447		0	WRNin Duck 3	-72.455%.%4		2 2	es weak.D
		UE0774Hurachi2329Faran "Paritian 42.myr	Prairie	294.29	\$\$4.2	Assolution	422.25	722.25	41.09666422		12	Windust 2	-72.24444545		2 2	en viskin D
	•	010774Haarki1101Peren "Parities 43.mpr UIC774Haarki1101Peren "Parities 44.mpr	Braking	242.5	942.5	Accelerating	425.75	124.5	41,25234624		104	Within Dack 3 Mithin Dack 2	-71.5-04-9949 -79.71799492		9 8	en stablice Se Piur SO
	- 2	UICT/Hughilth Foren Traitien 45.mar	Draking	275				70	23 00049219		16	WRAin Duck 2	-59,97992179		1 5	SE Piur St 24 Million D
	44	USC 77-04 www.hillipitPlanam."Planitian.dll.mov	Brabing	211.25			445.25	745.25	39.72911517		12	Within Dunk 2	-70.7298363		2 î	24 Within D
		007749 and 100 Person "Parities 42 may 007749 and 100 Person "Parities 43 may	Draking Braking	207.5		Accelerating	449.5	749.5	20.26454106		10	Within Duck 2 Vithin Duck 3	-72.22497545			De Mithin D
		UGT/Mushi101Peren "Parities 41 mor U0774Nushi101Peren "Parities 43 mor	Braking Draking	293.79	991.0	Accelerating	452.15	192.19	27.76658875			Vielus Duck 3	-73.5554.54210		1 1	24 VOLLO
		USC 77-0Househilth 1P or on "Presition \$3, ever	Brabing				493.25	199.25					-15.774264TT			
	- 10	US0774Harahi1991Paran "Paritian Statys	Deathing	36.5	642.1	Assolutions	462.5	762.5	27.28201419		101	Windus Dusk 2	-16.72647776		2 S	Ce VistinD
	52	UIGTTVHusehill91P or on "Parities \$2 mor	Braking	3\$1.75	411.2	Accolutations	455.75	765.75	37,21129431		1 10	WHINE Deck3	-77.54557%3		a >	24 WHAND
1		UIC774Harahi1991Paran "Paritian 52 ayu UIC774Harahi1991Paran "Paritian 54 ayu	Braking	225	431.0	Accoluration	472.25	714	27.28471462		0	Vikilis Durck 2 Vikilis Durck 3	-79.2272217N -78.31497264		a ;	De Visio D De Visio D
1	26	UIC774Huahilth1Peran "Parities 55.mar	Beaking	20.75	641.7	Accolutation	475.75	774.75	37,54354531		10	Within Deck 3	-75.42955176		3 3	CH VORIND
	57)	UIC774Harahi1991Paran "Paritim Stanya UIC774Harahi1991Paran "Paritim Stanya	Braking	251	65	Accelerating	415.25	712	27.56274864			Within Durch 2	-79.43541542		3 2	24 VIALD
1	- 22	UIC 7749 washi19919 or on "Parities 51, nor UIC 7749 washi19919 or on "Parities 51, nor	De sking Braking	294.25	494.2	Accolumnting	495.25	T15.25	27.14755195			VikinDuck2 VikinDuck3	-79,5339404		a :	Cel VisbinD
			Draking	244.75			491.75	791.75	27.1015564				-79.52472675			
		UIC774Huahil101Feran "Parities \$1.myr	Braking	375	67	Acceleration	645	745	37.50524797		101	Within Darek 3	-71.50209127		2 3	24 WHILD
			Draking	244.28			499.25	796.25					-78.46321992			
1	- 22	UG774Harahi1991Foron "Parition 53 may UG774Harahi1991Foron "Parition 54 may	Braking	347.5		Accoluration Accoluration	501.5 SM 75	001.5 194.75	37.22511952		0	Vikhis Deck 3 Vikhis Desk 2	-78,41445254		9	24 WebinE
	450	UICT74Huahil101Foron 7Farities 55 nor	Braking	493			100	202	32,50626255		29	WHINE Duck 4	-78.32242050		2 3	20131414.5
	44	URC774HarahilthHP or on "Paritian 55 mor	Deathing	414.25	744.21	Assalutating	\$11.25	911.25	24.00460745		25	Within Dush 4	-79.2470465		a i	OF WALLE
	670	UIGT74Hurshill91Foron/Fazition57.mov	Braking	49.5			514.5 512.35	114.5	39.72669377			Vikhis Duck 4	-79.29992072 -79.17947525			
-	- 12	UIC774Harahi199F or on "Parition 51, myr UIC774Harahi199F or on "Parition 53, myr	Braking Braking	41.75	211.2	Accoluration	\$17.15	117.75	21.00140925		29	VikbaDuck4 VikbaDuck4	-71.17967525		1 .	DE VINELE DE VINELE
							\$24 \$24,25	124.35	24 50244452				-29.27244996			
1	70	UROTT+Hurahilth)IP or on "Paritian True ya	Draking	401.5	127.1	Acceleration	527.5	127.5	31.10747777		10	Within Durck 3	-79.42259947		2 3	CA WIRKING
1			Braking					134.75								
-	- 2	UIC 774Hurahil991Foron "Paritian 73.myr	Draking Braking	63 45.25	75	Accolurating	524	024	20.01774132		2	Vikin Duck 2	-79.87303124		3 2	Ce Makin D
		UICT70Harachi1991F or on "Parition 74 may UICT70Harachi1991F or on "Parition 75 may	Deathing	4(2.5			543.5	141.5	22,35266474		10	Within Dusk 2	-79.23520125		3 5	Cel Vistin D
	76	UIC774Hushi101Feron "Parities 75 nor	Braking	415.75	768.7	Accoluteting	543.75	243.75	37.16443272		10	Within Duck3	-79.34319567		2 3	24 9944.0
			Deathing					047	27.85899921				-79.40075551			
		UICTT01cachilitiFaces Techins Theory	Brahing	411.25	781.25	Accelerating	\$54,25	192.5	37,0109195		10	VPNisDeck3 VPNisDeck3	-79,49300754		վ հ	Cel Minhin D
1	12	UIC779Howhi101Peren "Parities 78 avgr UIC779Howhi101Peren "Parities 78 avgr	Braking Braking	412.5			\$\$2.5 \$55.75	192.5	24.90011457 34.95351142			VikbisDuck3	-79.33799065		a ;	CHIVINELLE CHIVINELLE
1			Prairie	593			568	260	26.40154252		0	Within Dunk 2	-79.89724025			
1			Draking	501.25			913.25	(43.25	24.0021941		100	Mitchis Durch 2	-78.40176466		2 2	CENTRAL D
1		UIC776Harahi1991Paran "Paritian 13 mov	Braking	50.5	912.	Assalutating	511.5	166.5	22.51422244		25	Within Durch 4	-71.21195274		aj 3	De VINELD
		UIC774Haashi991Foron "Parition Hanys UIC774Haashi991Foron "Parition 15 myr	Draking Braking	541.75 525	918.2	Accolurating	545.75	069.75 872	26.9719993			ViklusDuck4 ViklusDuck3	-78.05996459 -77.15196797			24 Vitals D
1			Draking	825			\$74.25	075.25	34.00543937		0	Vision Duck 2				
			Braking	517.5			\$71.5	175.5	36.70103621				-77.24769244		3	24 Statio D
	+0	UI0774Harahi1991Paran "Paritian FLayor	Draking	\$40.75	(4).7	Accolorating	\$92.75	002.75	27.26465792		200	Within Duck 5	-77.12944753		2 3	24 Within D
		UIC774Hurshill)1P er en "Parities III.mor	Braking	551	15		526									28 551414.0

Figure 60: Axial Rail Stress Check Worksheet for Multiple Results Files

If valid basic combinations or envelopes that match the criteria described in **Postprocessing of automatically defined groups** (page 40) are present in the model then additional results for these will be tabulated into the Microsoft Excel summary worksheets underneath the results for the temperature only and combined temperature and trainset rail loading results. A separate set of the peak results within these basic combinations will be highlighted in bold blue text as illustrated in the figures below for the railbed displacement and reaction results for a model that includes valid basic combinations.

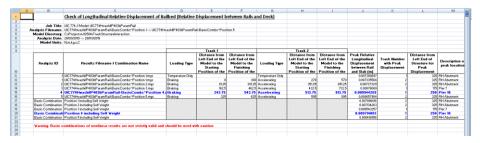


Figure 61: Railbed Check Worksheet for Rail Track Analysis Results and Basic Combinations of these Results

	A	B	C	D	E	F	G	H		J	K
			Check of Longitudinal Reactions								
-	_	•									
2		Job Title:	UIC 774-3 Model: UIC 774Hz adviP403bParamRail								
ā.			UIC774Hv ash/P403bParamPail-BasicCombs/Position 1> UIC774Hv as	hiP40%ParamPai-I	BasicCombs'Position 9						
5			C:Projects/J12504iTrackStructureInteraction								
6			28/03/2019> 28/03/2019								
7		Model Units:									
8											
9					Track 1			Track 2			
					Distance from	Distance from		Distance from	Distance from	Peak	Abutment / Pir
		Analysis ID	Results Filename / Combination Name	Loading Type	Left End of the	Left End of the	Loading Type	Left End of the	Left End of the	Longitudinal	Number with
		Analysis ID	Resurs Filename F Compilitation Hame	Loading type	Model to the	Model to the	coaunig type	Model to the	Model to the	Beaction (N)	Peak Reaction
10 11					Starting Position	Finishing		Starting Position	Finishing		
			UIC774Hv ashiP403bParamRail-BasicCombs'Position 1.mys	Temperature Only			Temperature Only			300463.4131	
12				Braking	0		Accelerating	270	570	287207.5788	
13			UIC774Hv ashiP403bParamRail-BasicCombs*Position 2 mys	Braking	81.25		Accelerating	351.25	651.25	-645077.2753	
14			UIC774Hv ashiP403bParamRail-BasicCombs'Position 3.mys	Braking	162.5		Accelerating	432.5	732.5	-837591.4175	
15			UIC774HwashilP403bParamRail-BasicCombs*Position 4.mys	Braking	243.75	543.75	Accelerating	513.75	813.75	-1201042.32	
16		5	UIC774Hv ashiP403bP aramRail-BasicCombs' Position 5.mys	Braking	325	625	Accelerating	595	895	-1191058.888	Pier 11
17		Basic Combination	Position Lincluding Self Weight							262674.6646	Pier 5
18		Basic Combination	Position 2 including Self Weight							-643660.0864	Pier 3
19		Basic Combination	Position 3 including Self Weight							-836174.2286	Pier 3
20			Position 4 including Self Weight							-1214172.798	
21		Basic Combination	Position 5 including Self Weight							-1199972.026	Pier 11
22											
23		Warning: Basic ce	ombinations of nonlinear results are not strictly valid and show	dd be used with o	aution						
21 22 23 24 25											
25											

Figure 62: Longitudinal Reaction Check Worksheet for Rail Track Analysis Results and Basic Combinations of these Results

Microsoft Excel Fails with Insufficient Resources when Enveloping

If Microsoft Excel fails to complete the post-processing successfully with a complaint of insufficient resources (with messages similar to the ones in the following figure) when performing the enveloping within Microsoft Excel the post-processing will need to be carried out using a different method. These memory limitations with Microsoft Excel are dependent upon both the size of the rail track model being post-processed and the number of results files loaded.

Microsoft .	NET Framework	×
\bigotimes	Unhandled exception has occurred in a component in y application. If you click Continue, the application will ig and attempt to continue.	
	Not enough storage is available to complete this opera from HRESULT: 0x8007000E (E_OUTOFMEMORY)).	ition. (Exception
🔺 Det	ails	Continue
	d of this message for details on invoking (JIT) debugging instead of this dialog box.	1
System.Du at Micros at Micros at MSEx at MSEx	⁶⁶ Exception Text ⁸⁰⁰ Exception: Not enough storage is available to t0/fMemoryException: Not enough storage is available to oft/VisualBasic.CompilerServices.LateBinding_LateGet(01 oft/VisualBasic.CompilerServices.NewLateBinding_LateGet(01 oft_VisualBasic.CompilerServic	pject o, Type objT et(Object Instanc) ataLabels(Object (Obj, Object Excel
🔝 Micros	oft Excel	×
8	Excel cannot complete this task with available resou less data or close other applications.	rces. Choose
		OK

Figure 63: Insufficient Resources for Microsoft Excel to Complete the Post-Processing



Note. After the failure of a post-processing the Microsoft Excel application may still be dormant on the computer and may need to be terminated by ending the process in Windows Task Manager. The Rail Track module is also likely to have been disabled in LUSAS Modeller and a message reported such as "An error occurred in LUSAS Module UIC774-3. Error LateGet: The remote procedure call failed. Please contact LUSAS technical support. Module Controller has caught an unhandled exception in debug module UIC774-3." <u>This is caused by the failure of Microsoft Excel and there is no need to contact LUSAS technical support but the Rail Track module will remain disabled until LUSAS Modeller is closed down and restarted.</u>

If there are insufficient resources for Microsoft Excel to carry out the enveloping of the analyses and it is not appropriate to increase the size of the elements used for the modelling of the analysis or reduce the number of trainset positions then two automatic post-processing options are generally available. The first option is to post-process the results files in smaller groups to minimise the amount of memory that Microsoft Excel needs for holding the data. The number of results files loaded can be altered by choosing the File>Manage Results Files... option. Disable the 'Let LUSAS manage results files (recommended)' option (a warning will be issued but this can be ignored so long as the model is not saved). Deselect the analysis results to exclude by unticking the checkboxes in the 'Open' column and click the OK button. This will close those results chosen and allow the post-processing to be performed only on the results that remain loaded.



Caution. Do not save the model with the 'Let LUSAS manage results files (recommended)' option disabled. If it has been turned off then it should be turned back on if the model is saved.

This is illustrated in the figures below which illustrate the process. Select **File>Manage Results Files...** to bring up the results management dialog shown in Figure 64. Uncheck the "Let LUSAS manage results files (recommended)" checkbox – this will cause a warning to be issued which can be ignored. Within this dialog, deselect the opening of results files which are to be excluded from the post-processing (Positions 2 and 4 are deselected in the figure) and click OK. The automatic post-processor can now be run (with or without the enveloping in Microsoft Excel) but it will bring up the information message shown in Figure 65 indicating that insufficient results files are loaded for the analyses in the model. Click on OK since we know why this is the case. The automatic post-processor will continue with the extraction of results but with the deselected positions / results files omitted as indicated in Figure 66.

ler fo	r files whose locati	on is not specified	C:\Projects\J12504\TrackStructureInteraction\Associated Model Data\	ManageResult	s	
ID	Analysis		Filename		Open	Remove
1	Position 1		ManageResults~Position 1.mys		₹	Remove
2	Position 2		ManageResults~Position 2.mys			Remove
3	Position 3		ManageResults~Position 3.mys			Remove
4	Position 4		ManageResults~Position 4.mys			Remove
5	Position 5		ManageResults~Position 5.mys			Remove
,	Position 3		Managerressiks in Usikun Siniys		I.	<u> </u>

Figure 64: Turning Off LUSAS Management of Results Files

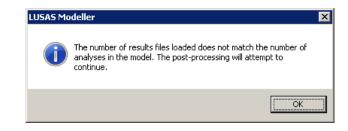


Figure 65: Post-Processor Information Message About Loaded Results

	В	C	D	E	F	G	Н		J	К
1		Check of Longitudinal Reactions								
2										
3		UIC 774-3 Model: ManageResults								
4		ManageResults'Position 1> ManageResults'Position 5								
5		C:VProjectsVJ12504\TrackStructureInteraction								
6		29/03/2019> 29/03/2019								
7	Model Units:	N,m,kg,s,C								
8										
9				Track 1			Track 2			
	Analysis ID	Results Filename	Loading Type	Distance from Left End of the Model to the	Distance from Left End of the Model to the	Loading Type	Distance from Left End of the Model to the	Distance from Left End of the Model to the	Peak Longitudinal Reaction (N)	Abutment / Pier Number with Peak Beaction
10				Starting Position	Finishing		Starting Position	Finishing		
11		ManageResults'Position 1.mys	Temperature Only			Temperature Only			300463.4131	
12		ManageResults'Position 1.mys	Braking	0		Accelerating	270	570	287207.5788	
13	2	ManageResults'Position 3.mys	Braking	162.5		Accelerating	432.5	732.5	-837800.7498	
14	3	ManageResults Position 5.mys	Braking	325	625	Accelerating	595	895	-1191058.888	Pier 11
15										

Figure 66: Longitudinal Reactions for User Managed Results

The advantage of this first option is that it still allows the creation of the additional summary tables of derived quantities such as the relative railbed displacements. The second option is to perform the enveloping in Modeller itself which is illustrated below. The disadvantage of this method is the inability to envelope derived quantities such as the relative railbed displacements. Calculation of the relative railbed displacement from enveloped values of the displacement of the structure and the track will result in the incorrect value being reported and is therefore disabled.

The envelopes can be defined manually but for the number of results files that are generally used for the rail track analyses for analysing different trainset positions it is

easier to define the envelopes using VBScript. Figure 67 shows an example of a VBScript file that will automatically generate the equivalent envelopes for 101 separate results files loaded on top of the model. If a different number of results files are to be considered then the line that reads numResFile = 101 can be changed to the number required. Alternatively if enveloping is always going to be performed over all of the results files loaded then this line can be replaced with numResFile =

```
database.countResultsFiles() .
```

```
SENGINE=VBScript
 Sample VBScript to define envelopes in Modeller equivalent to those carried out
' in Microsoft Excel
' The number of results files loaded on top of the model
numResFile = 101
' Define the envelope objects
Set envTempOnly = database.createEnvelope("Envelope of Temperature Only")
Set envTempTrain = database.createEnvelope("Envelope of Temperature and Train Loads")
Set envAllConfig = database.createEnvelope("Envelope of All Configurations")
' Loop over the results files
For ires = 1 To numResFile
 Add the temperature only results to the appropriate envelopes
    Call envTempOnly.addEntry(1, ires, -1, -1)
    Call envAllConfig.addEntry(1, ires, -1, -1)
' Add the temperature and train results to the appropriate envelopes
    Call envTempTrain.addEntry(2, ires, -1, -1)
    Call envAllConfig.addEntry(2, ires, -1, -1)
Next
' Release envelope objects
Set envTempOnly = Nothing
Set envTempTrain = Nothing
Set envAllConfig = Nothing
```

Figure 67: Example VBScript to Define Equivalent Envelopes in Modeller

If the envelopes in Modeller have been defined correctly then identical results will be obtained from the post-processor for the Modeller and Microsoft Excel enveloping methods. Generation of the envelopes in Modeller through VBScripting removes the potential for errors in the generation of these envelopes and is therefore recommended, particularly for large numbers of results files.

Figure 68 and Figure 69 show the results from the enveloping of the combined temperature and trainset loading for the track of a model. Comparison of the tables and graphs shows that the results are identical for both enveloping methods. In Figure 69 which shows the results for the track from enveloping in Modeller both the summary tables and the graphs have omitted the relative railbed displacement results because these cannot be calculated from the enveloping in Modeller.

Figure 70 and Figure 71 show the results from the enveloping of the combined temperature and trainset loading for the deck of a model. Comparison of the tables and graphs shows that the results are identical for both enveloping methods.

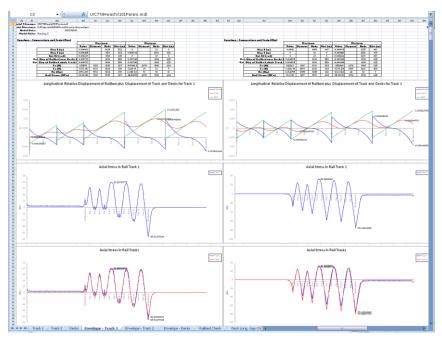


Figure 68: Track Envelopes Performed in Microsoft Excel

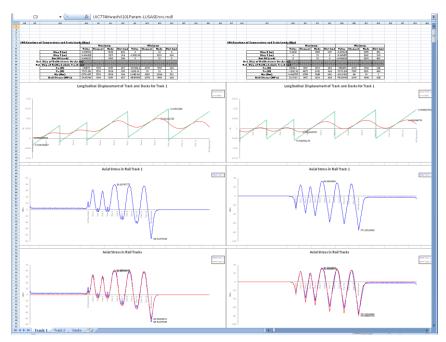


Figure 69: Track Envelopes Performed in Modeller

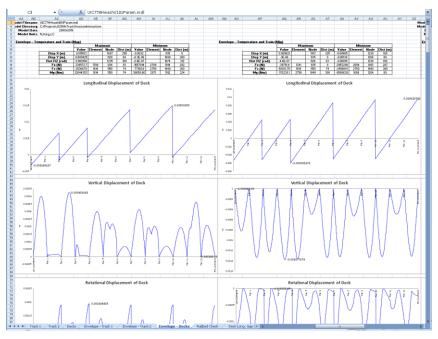


Figure 70: Deck Envelopes Performed in Microsoft Excel

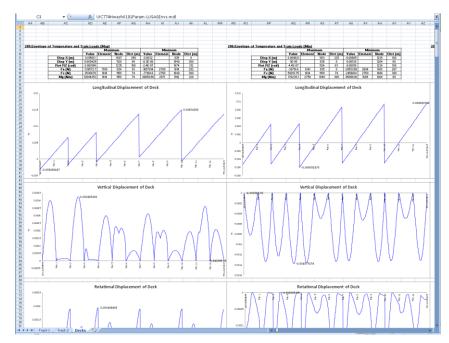


Figure 71: Deck Envelopes Performed in Modeller

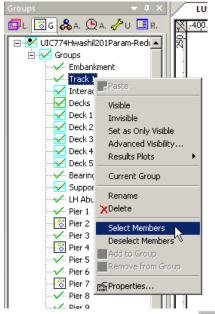
One final option available (that should be used with caution, particularly if there is a possibility for the peak behaviours in the track / railbed being observed over any part of the embankments rather than over the structure) is the reduction of the track/rail groups in the model so that they contain the bare minimum of features/mesh over the embankments plus all of the track/rail over the structure. Any modifications of this sort should be done after first making a backup copy of the original model in case the editing corrupts the model.

In the rail track analysis model:

 \square Ensure the whole model is visible and that the selection allows the selection of

any geometry and mesh features with the Select Any cursor 1,

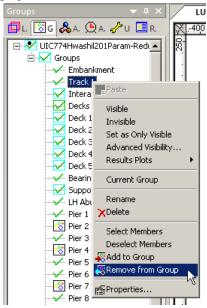
□ In the **Groups Treeview** select all of the members in the **Track 1** group by right-clicking on the **Track 1** group and choosing the **Select Members** option as illustrated below,



- □ Create a copy of the **Track 1** group by clicking on the ¹ button to create a new group and give it the name **Copy of Track 1**,
- □ If there is more than one track, repeat the two steps above to create a copy of each of the track groups in the model (ensuring that the features from the previous tracks are deselected first before selecting those from other tracks),
- □ Clear the selection and then select the track features and mesh to be removed from the post-processing as illustrated below ensuring that the extremes of the embankments are not selected (far left and right along with embankment next to the structure **must** not be selected),



□ Remove the selected features and mesh from the **Track 1** group by rightclicking on the **Track 1** group in the **Groups Treeview** and choosing the **Remove from Group** option as illustrated below,



- □ If there is more than one track, repeat the removing of the features and mesh from all of the remaining track groups,
- □ Save the model,
- □ Post-process the model as before.

In the example below the post-processing of the 201 parametric trainset positions initially failed due to insufficient resources in Microsoft Excel. On removing most of each of the two embankments the full 201 parametric trainset positions could be post-processed successfully in Microsoft Excel.



Note. This approach may not always work and is generally more applicable when the lengths of the embankments are similar to the length of the structure. If the embankment lengths are significantly smaller than the length of the structure minimal change in the computer memory usage by Microsoft Excel will be observed.



Caution. The extremes of the track/rail over the embankments must be left within the track groups to ensure that the post-processing is carried out correctly. Errors may be observed and inaccurate results obtained if this is not the case.



Caution. Excluding the embankments from the track could give misleading results if the peak behaviours actually occur over the embankments, especially close to the transition between the embankment and the structure, rather than over the structure itself. Judgement should be exercised before accepting the results after exclusion of the embankments.

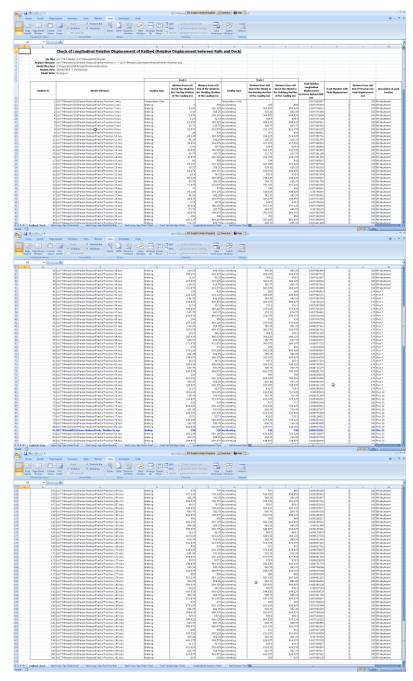


Figure 72: Railbed Enveloped Results for 201 Parametric Trainset Positions in Microsoft Excel

Post-processing of selected track / rail nodes

If spot checks need to be performed at specific locations on the tracks, the nodes of the track/rail can be post-processed individually. To perform the post-processing the selection in the LUSAS model created by the Rail Track Analysis spreadsheet <u>must</u> contain nodes that are part of the track/rail. If nodes from other parts of the model are selected then these nodes will be ignored. All other selected objects will also be ignored.

Figure 73 shows sample output from the post-processing of a track. For each results file that is loaded the axial stress at the node(s) will be reported in a separate worksheet for each node.

A	B	C C	D	3	F	0	н	1	J
		Check of Axial Rail Stress for Track 1, No	de 1021 X-22 0 X-0 0	7-0.0					
_		Check of Axial Rall Stress for Track 1, No	de 1031 X-32.0 1-0.0	2=0.0					
	Job Title	c UIC 774-3 Model: UIC774HwashilP403bParamRail							
		e: UIC774HwashiIP403bParamRail*Position 1> UIC774HwashiIP403	Correct DailWith still on #						
		c C/Projects/J12504/TrackStructureInteraction	or a annual roomon o						
		e: 21.03.19> 21.03.19							
		st N.m.kg.s.C							
	interest of the	a namos a so							
				Track1			Track 2		
				Distance from Left End	Distance from Left End			Distance from Left End	
	Analysis ID	Results Filename	Loading Type	of the Model to the Starting Position of the Loading (m)	of the Model to the Finishing Position of the Loading (m)	Loading Type	of the Model to the Starting Position of the Loading (m)	of the Model to the Finishing Position of the Loading (m)	Axial Stress of Rai Track 1, Node 10 (MPa)
- +		1 UIC774HwashilP403bParamRail*Position 1.mys	Temperature Only	the coating (m)	the coating (m)	Temperature Only	che coading (m)	one coading (m)	15.4592
		1 UIC774HwashiP403bParamRail*Position 1.mys	Braking		900	Accelerating	270	570	14.97405
		2 UIC774HwashilP403bParamRail*Position 2.mvs	Braking	81.25		Accelerating	351.25	651.25	16,1806
		3 UIC774HwashilP403bParamRail*Position 3.mys	Braking	162.5		Accelerating	432.5	732.5	16.5359
		4 UIC774HwashilP403bParamRail*Position 4.mys	Braking	243.75		Accelerating	513.75		
		5 UIC774HwashilP403bParamRail*Position 5.mys	Braking	325		Accelerating	595	895	16.7789
						0			

Figure 73: Sample Output from an Individual Track/Rail Node

Note. The stresses reported in the track/rail node worksheets are the averaged nodal stresses. The stresses reported previously in the post-processing performed on the UIC774-3 groups is the unaveraged nodal stresses and therefore the values will differ slightly. The averaged nodal stresses can be obtained for the post-processing of the UIC77-3 groups by averaging the values reported for the elements either side of the node.

Post-processing of selected lines if groups are missing

If the model does not contain the expected rail track model group names ("Track 1", "Track 2" and "Decks") or expected group contents then post-processing can be carried out on a line by line basis. To use this option the selection <u>must</u> contain lines that have 3D Thick Beam elements assigned. All other lines and objects will be ignored by the post-processor.

When post-processing selected lines it is assumed that these lines define a single path which travels in the direction of increasing line ID number. The lines will therefore be post-processed in increasing line ID order and the lowest line ID start point will be assumed to provide the reference position for the x-coordinate used to calculate the distances reported.

The output is almost identical to the output that is generated for the decks group with a summary table and tabulated output reported for all of the elements associated with the lines that have been selected. No graphs are generated for the post-processing of the selected lines since the distances may not be sequential if lines of the tracks / rails or decks have been omitted from the selection as illustrated in Figure 74 where there is a jump between distances of 10 and 32 m. Results are output for the temperature only (Increment 1) and the combined temperature and trainset loading (Increment 2) with additional results files tabulated from left to right in the worksheet. If basic combinations or envelopes have been defined in the LUSAS model the results from these will also be output to the worksheet if they can be post-processed.

	A	В	С	D	E	F	G	н	1	J	К	L	M	N	0
1	Job Title:	UIC 774-3	Model: UIC774HwashilP403b	ParamRail											
2															
3	Analysis F	Filename:	UIC774HwashilP403bParam	Rail_Selection	"Position 1.	mys									
4	Analysis I	Directory:	C:\Projects\J12504\TrackStr	uctureInterac	tion\Associa	ted Model	Data\UIC774	HwashilP403	bParamRail_	Selection\					
5	Anal	ysis Date:	21/03/201	9											
6	Mo	del Units:	N,m,kg,s,C												
7															
	1:Position	1 - Deck T	emp (Manual NL)										2:Position	1 - Train Load	5
9					Maxi					mum					
LO				Value	Element	Node	Dist (m)	Value	Element	Node	Dist (m)				
11			Disp X (m)	0.00967877		1913	325	-0.0060961		1238	100				Disp X (r
12			Disp Y (m)	2.0418E-05		1873	311	-4.158E-05		1802	288				Disp Y (
13			Rot RZ (rad)	4.9038E-06		1831	297	-4.756E-06		1772	278				Rot RZ (r
14			Fx (N)	-40000.004	1241	935	0	-2501146.1	2684	1801	287				Fx (N)
15			Fz (N)	80060.2031	2504	1692	251	-80672.923	2866	1909	323				Fz (N)
16			My (Nm)	416626.112	1870	1311	125	-252978.33	2684	1801	287				My (Nn
17									0-107						
18	Element	Node	Distance (m)	X (m)	¥ (m)	Z (m)	Disp X (m)	Disp Y (m)	Rot RZ (rad)	Fx (N)	F2 (N)	My (Nm)	Element	Node	Distance
9	1241	935		0 0				6.9234E-08			64034.9151	-4702.546	1241	935	
20	1241	937		1 1	0			-2.577E-06			64034.9151	-4702.546	1241	937	
21	1248	937		1 1				-2.577E-06			63922.0081		1248	937	
22	1248	942		2 2				-5.196E-06			63922.0081		1248	942	
23	1253	942		2 2				-5.196E-06			63932.5372		1253	942	
4	1253	943		3 3	0		-0.0047363				C9 32.5372		1253	943	
25	1256	943		3 3 4 4	0		0 -0.0047363				63933.0285		1256	943	
26 27	1256 1263	948 948		4 4 4 4	0			-1.025E-05			63933.0285 63932.7843		1256 1263	948 948	
28	1263	940		4 4 5 5	0			-1.263E-05			63932.7843		1263	940	
28 29	1263	951		5 5	0		0.0043383				63932.8089		1263	951	
19	1267	951		5 5 6 6	0		0.0043385				63932.8089		1267	951	
1	1267	952		o o 6 6	0		0.0041396				63932.8097		1267	952	
	1273	957		7 7				-1.695E-05		-520000.04			1273	957	
2	1276	957		7 7				-1.695E-05			63932.8092		1276	957	
		958		8 8	0			-1.885E-05	-1.81E-06		63932.8092		1276	958	
3	1276	958		8 8	0		-0.0037431		-1.81E-06		63932.8093		1282	958	
3	1276				0		-0.0035452				63932.8093		1282	963	
13 14 15		963		9 9						760000.05	63932.8093	-90227.129	1288	963	
13 14 15	1282			9 9	0		0 -0.0035452	-2.053E-05	-1.581E-06						
13 14 15 16	1282 1282	963		9 9				-2.053E-05 -2.197E-05			63932.8093		1200	964	
13 14 15 16 18	1282 1282 1288	963 963	1	9 9 0 10	0		-0.0033475		-1.326E-06		63932.8093	-90227.129			
13 14 15 16 18	1282 1282 1288 1288	963 963 964	1	9 9 0 10 0 10	0		-0.0033475	-2.197E-05 -2.197E-05	-1.326E-06 -1.326E-06	-760000.05 -840000.05	63932.8093	-90227.129 -99734.322	1288	964	
32 33 34 35 36 37 38 39 40 41	1282 1282 1288 1288 1288 1293	963 963 964 964	1	9 9 0 10 0 10 1 11	0		0 -0.0033475 0 -0.0033475	-2.197E-05 -2.197E-05 -2.314E-05	-1.326E-06 -1.326E-06 -1.044E-06	-760000.05 -840000.05 -840000.05	63932.8093 63932.8093	-90227.129 -99734.322 -99734.322	1288 1293	964 964	

Figure 74: Sample Output from Post-Processing of Selected Lines when the Groups are Missing or Invalid

If more than one results file is loaded, basic combinations are defined in the model that may be post-processed (see the restrictions under the **Post-processing of automatically defined groups** section on page 40) and enveloping in Microsoft Excel has been selected then the Microsoft Excel spreadsheet will contain an additional

worksheet that holds these enveloping results. The envelopes generated will be the same as those for the tracks and decks:

- □ Maximum and minimum envelopes for temperature loading only
- □ Maximum and minimum envelopes for temperature and trainset rail loading
- □ Maximum and minimum envelopes for all of the basic combinations defined in the model (if valid basic combinations are present)
- □ Maximum and minimum envelopes for all configurations (an envelope of the above results)

The following figure illustrates the tabulated enveloped results when selected lines are post-processed if expected model groups are either missing or invalid. No automatic graphing is possible when post-processing with enveloping in Microsoft Excel is carried out on selected lines (since these lines may not be continuous). Should graphs of the results be required then these can either be defined manually within the generated Microsoft Excel spreadsheet or the data can be copied and pasted from the spreadsheet.

1	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM
Ē						. 10			110						
ŀ	Model F	ilename:	UIC774HwashiIP403bParam	Pail Selection	mdl		¢.								
t			C:\Projects\J12504\TrackStr				U								
		del Date:			(non i										
			N,m,kg,s,C												
E	Envelope -	Tempera	ture and Train (Max)										Envelope	- Temperatur	and Train (Mi
					Maxi	mum			Minii	mum					
1				Value	Element	Node	Dist (m)	Value	Element	Node	Dist (m)				
			Disp X (m)	0.0143805		1687	250	-0.0033348		935	0				Disp X (r
			Disp Y (m)	0.00039559		978	14	-0.0005523		1655	239				Disp Y (r
			Rot RZ (rad)	0.00019162		1913	325	-8.141E-05		1688	250				Rot RZ (r
			Fx (N)	182686.394	1462	1066	44	-2104769.2	2714	1819	293				Fx (N)
			Fz (N)	2435953.25	1614	1159	74	-1232195.8	2374	1614	225				Fz (N)
5			My (Nm)	9516215.75	1614	1159	74	-3754965	2448	1657	240				My (Nn
7															
1	Element	Node	Distance (m)	X (m)	Y (m)	Z (m)	Disp X (m)	Disp Y (m)	Rot RZ (rad)	Fx (N)	Fz (N)	My (Nm)	Element	Node	Distance
	1241	935		0 0	0	C	-0.0033348	1.8213E-07	4.3536E-05	48334.695	166476.689	104000.364	1241	935	
	1241	937		1 1	0	C	-0.0031354	4.3612E-05	4.3242E-05	48334.695	166476.689	104000.364	1241	937	
	1248	937		1 1		0	-0.0031354	4.3612E-05	4.3242E-05	113901.23	168380.233	295707.603	1248	937	
	1248	942		2 2		0	-0.0029372	8.6476E-05	4.2406E-05	113901.23	168380.233	295707.603	1248	942	
	1253	942		2 2	0	0	-0.0029372	8.6476E-05	4.2406E-05	152798.771	168179.568	473568.153	1253	942	
	1253	943		3 3	0	0		0.00012825					1253	943	
	1256	943		3 3	0		-0.0027403						1256	943	
	1256	948		4 4	0		-0.0025445				168175.387		1256	948	
	1263	948		4 4	0	C		0.00016846			168180.183		1263	948	
	1263	951		5 5	0		-0.0023496						1263	951	
	1267	951		5 5		0		0.00020664					1267		
	1267	952		6 6	0		-0.0021556						1267	952	
		952			0		-0.0021556						1273	952	
	1273	077									168180.834	10/6486.13	1273	957	
	1273	957		7 7					2 12175 05		160101 202	1007661 74	1276	057	
	1273 1276	957		7 7	0	C	-0.0019623	0.00027525		73572.5221			1276	957	
	1273 1276 1276	957 958		7 7 8 8	0	0	-0.0019623 -0.0017697	0.00027525 0.0003049	2.7902E-05	73572.5221 73572.5221	168181.283	1207551.74	1276	958	
	1273 1276 1276 1282	957 958 958		7 7 8 8 8 8	0	0 0 0	-0.0019623 -0.0017697 -0.0017697	0.00027525 0.0003049 0.0003049	2.7902E-05 2.7902E-05	73572.5221 73572.5221 20687.8385	168181.283 168181.658	1207551.74 1332968.21	1276 1282	958 958	
	1273 1276 1276 1282 1282	957 958 958 963		7 7 8 8 8 8 9 9	0	0 0 0	-0.0019623 -0.0017697 -0.0017697 -0.0015774	0.00027525 0.0003049 0.0003049 0.00033095	2.7902E-05 2.7902E-05 2.4132E-05	73572.5221 73572.5221 20687.8385 20687.8385	168181.283 168181.658 168181.658	1207551.74 1332968.21 1332968.21	1276 1282 1282	958 958 963	
	1273 1276 1276 1282 1282 1288	957 958 958 963 963		7 7 8 8 8 8 9 9 9 9	0 0 0 0 0 0 0 0	0 0 0 0	-0.0019623 -0.0017697 -0.0017697 -0.0015774 -0.0015774	0.00027525 0.0003049 0.0003049 0.00033095 0.00033095	2.7902E-05 2.7902E-05 2.4132E-05 2.4132E-05	73572.5221 73572.5221 20687.8385 20687.8385 -40443.462	168181.283 168181.658 168181.658 168181.98	1207551.74 1332968.21 1332968.21 1453562.43	1276 1282 1282 1288	958 958 963 963	
	1273 1276 1276 1282 1282 1288 1288	957 958 958 963 963 964	1	7 7 8 8 8 8 9 9 9 9 9 9 9 9 0 10	0 0 0 0 0	0 0 0 0 0 0	-0.0019623 -0.0017697 -0.0017697 -0.0015774 -0.0015774 -0.0013854	0.00027525 0.0003049 0.0003049 0.00033095 0.00033095 0.00035307	2.7902E-05 2.7902E-05 2.4132E-05 2.4132E-05 2.0022E-05	73572.5221 73572.5221 20687.8385 20687.8385 -40443.462 -40443.462	168181.283 168181.658 168181.658 168181.98 168181.98	1207551.74 1332968.21 1332968.21 1453562.43 1453562.43	1276 1282 1282 1288 1288	958 958 963 963 964	
	1273 1276 1276 1282 1282 1288 1288 1288 1293	957 958 958 963 963 964 964	1	7 7 7 8 8 8 9 9 9 9 9 9 0 10 0 10	0 0 0 0 0 0		-0.0019623 -0.0017697 -0.0017697 -0.0015774 -0.0015774 -0.0013854 -0.0013854	0.00027525 0.0003049 0.0003049 0.00033095 0.00033095 0.00035307 0.00035307	2.7902E-05 2.7902E-05 2.4132E-05 2.4132E-05 2.0022E-05 2.0022E-05	73572.5221 73572.5221 20687.8385 20687.8385 -40443.462 -40443.462 -108609.44	168181.283 168181.658 168181.658 168181.98 168181.98 168182.254	1207551.74 1332968.21 1332968.21 1453562.43 1453562.43 1570037.51	1276 1282 1282 1288 1288 1288 1289	958 958 963 963 964 964	
	1273 1276 1276 1282 1282 1288 1288	957 958 958 963 963 964	1	7 7 7 8 8 8 9 9 9 9 9 9 9 0 10 0 10 1 11	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	-0.0019623 -0.0017697 -0.0017697 -0.0015774 -0.0015774 -0.0013854	0.00027525 0.0003049 0.0003049 0.00033095 0.00033095 0.00035307 0.00035307 0.00035307	2.7902E-05 2.7902E-05 2.4132E-05 2.4132E-05 2.0022E-05 2.0022E-05 1.5581E-05	73572.5221 73572.5221 20687.8385 20687.8385 -40443.462 -40443.462 -108609.44 -108609.44	168181.283 168181.658 168181.658 168181.98 168181.98 168182.254 168182.254	1207551.74 1332968.21 1332968.21 1453562.43 1453562.43 1570037.51 1570037.51	1276 1282 1282 1288 1288	958 958 963 963 964	

Figure 75: Sample Output from Post-Processing of Envelopes for Selected Lines when the Groups are Missing or Invalid

Limitations of Use

- □ Since the analysis is two-dimensional (even though three-dimensional elements are used) the offsets are not modelled for the bearing/section centrelines nor for the section/rail centrelines (see figure below). Currently all track centrelines are coincident with the centreline of the deck.
- □ Curved bridges cannot be modelled.
- □ Only up to two tracks can be considered in accordance with UIC774-3.
- □ Thermal loading for mixed steel and concrete bridges in the same model cannot be generated through the input spreadsheet. The model can however be modified to include these different thermal loads if no rail loading is applied when the model is built and the resulting LUSAS model modified manually. Care should be taken carrying this out and generally only additional temperature loading attributes should be defined and assigned to the model.

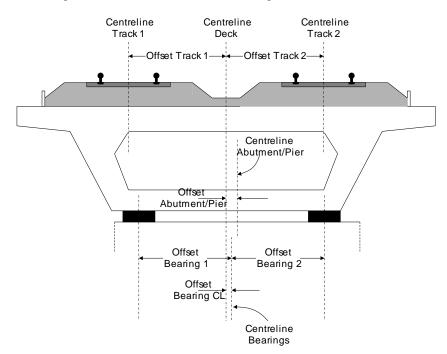


Figure 76: Offsets of Tracks/Bearings/Piers from Centreline Of Deck

Appendix A: Verification Testing

Introduction

This appendix includes some background to the calculation of the UIC774-3 track/bridge interaction analyses in LUSAS. It explains why results from running a LUSAS nonlinear analysis that considers all thermal and train effects for the test cases in question in <u>one analysis</u> does not over-predict the rail stresses occurring under the combined thermal and rail loading - unlike results from simplified hand calculations or from results from other finite element analysis software systems where thermal and train effects are carried out by running <u>separate nonlinear analyses</u>.

From the verification testing carried out we can say that...

Even though a computer program may be validated against the standard test cases in the UIC774-3 code of practice, in situations when combined thermal and train loading from separate analyses gives track-structure interaction forces that exceed the stated yield resistance of the track-restraint system (i.e. the ballast) then the separate analysis method will potentially overpredict the rail stresses unless the loaded track yield surface is reduced by the mobilised track resistance over the extent of the train loading. Rail stress over-predictions of up to 30% have been seen when thermal and train loading results are combined from separate analyses.

Description

The rail track analysis (UIC774-3) option in LUSAS allows the construction and solution of finite element models to study the interaction between the rail track and a bridge. This forms an essential part of the design process as the stresses within the rails of the tracks must remain within specified limits based upon the design and the state of maintenance. A number of calculation methods are available and each of these can lead to a slightly different solution for the combined thermal and rail loading condition. Each of these methods (except the hand calculation) has been investigated in this technical note prior to carrying out the analysis in LUSAS using the rail track analysis option. In all tests 1.0 m element sizes have been used.

The Hwashil Viaduct, a railway bridge in South Korea, has been used for this testing with continuous welded rail (CWR) and thermal effects only present in the structure for the following analyses:

- **Combination of Separate Thermal And Rail Loading**
- **Analysis Of Combined Thermal And Rail Loading (One Step)**
- □ Analysis Of Combined Thermal And Rail Loading Taking Account Of Effects Of Material Change Under Rail Loading

In addition, two of the UIC standard test cases have also been reinvestigated to demonstrate that these results can be matched even if the analysis type is potentially invalid prior to providing guidance and conclusions on this type of analysis. These analyses were:

- □ Revisit Of UIC774-3 Test E1-3 Using The Separate And LUSAS Methods Of Analysis
- Revisit Of UIC774-3 Test H1-3 Using The Separate And LUSAS Methods Of Analysis

Combination of Separate Thermal and Rail Loading

In this form of analysis two or more separate analyses are carried out with each analysis considering a different loading regime to the structure. This is the simplest form of analysis of the track/bridge interaction as it assumes that superposition is valid for a nonlinear system and, according to the UIC774-3 code of practice, can generally overestimate the rail stresses with percentage errors up to 20 to 30% be it through hand calculation or computer methods.

This analysis procedure is replicated in LUSAS by performing two separate nonlinear analyses. The first considers only the thermal effects and uses the unloaded resistance bilinear curve for modelling the interaction between the track and bridge. The results of this analysis are identical for the two tracks in the model and so only the results for the first track are presented in the following figure.

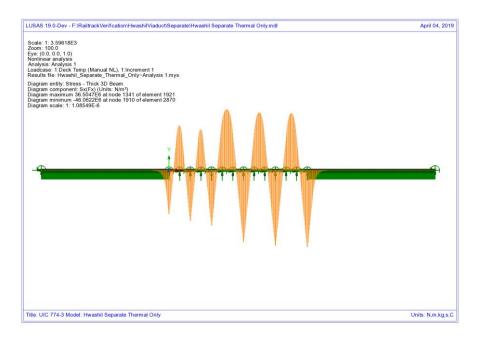


Figure 77: Axial Stress In Rails Due To Thermal Effects Only

These thermal effects give a peak compressive rail stress of 46.06 N/mm². Having carried out the thermal analysis the rail loading will be considered in a separate analysis (both horizontal and vertical loading) for the 'worst' conditions. This rail load analysis is again a nonlinear analysis but it has no knowledge of the history from the thermal effects and therefore assumes a zero strain initial state prior to the application of the load. In addition to this unstrained condition, the loaded resistance bilinear curve is used underneath the locations of the rail loading while the unloaded lengths of track use the unloaded resistance bilinear curve. The results from the rail loading analyses are presented in the following two figures, the first being the track that has the braking train loading and the second being the track that has the accelerating train loading.

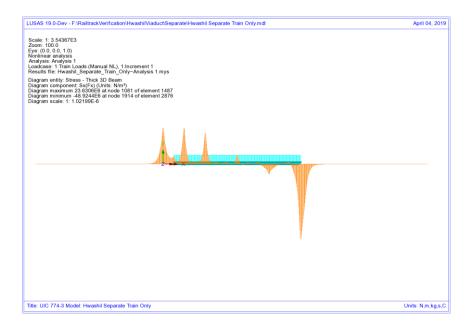
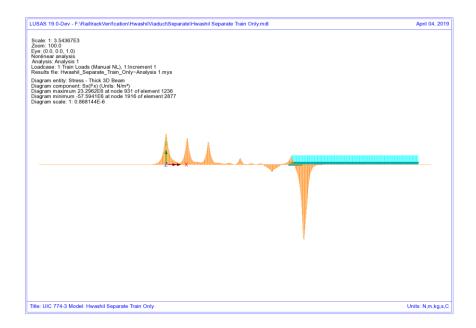


Figure 78: Axial Stress In Rails Due To Braking Train Loads On Track 1





From these results the peak compressive rail stresses for the two tracks are as follows:

Track 1:	48.92 N/mm ²
Track 2:	57.59 N/mm ²

A basic combination of the loading can be defined to add the results from the thermal and rail loading analyses together which gives the following track peak compressive stresses (see following figures):

Track 1:	94.99 N/mm ²
Track 2:	103.66 N/mm ²

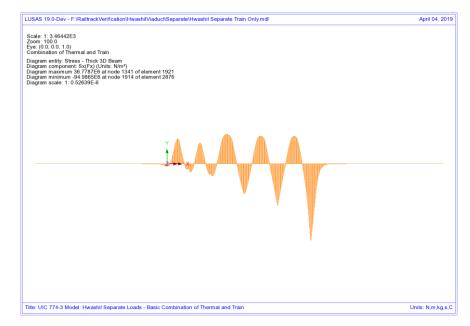


Figure 80: Axial Stress In Rails Due To Combined Thermal And Train Loads In Track 1

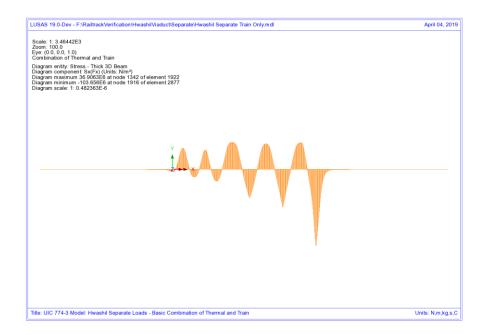


Figure 81: Axial Stress In Rails Due To Combined Thermal And Train Loads In Track 2

Inspection of the two plots shows that there is a reduction in the axial rail stresses over the first two deck transition piers towards the left end of the structure for track 1 only (subjected to the braking train). The following figures show zoomed plots of the rail axial stress for this location with the thermal diagram showing identical values either side of these piers for all of the decks in the model. The reason for the reduction in the axial stress becomes clear from the axial stress diagram for the train braking load alone, Figure 83, where the axial stress has a positive peak over the deck transition piers which is not symmetrical. Looking at the transition from the first deck to the second (2^{nd}) pier from left abutment) the axial stress in the rail over the end of the first deck is equal to a tensile stress of 23.63 N/mm² while the axial stress over the start of the second deck is equal to a tensile stress of 22.47 N/mm². Like for like comparison of the elements a certain distance from the pier for each deck shows that the second deck is consistently lower and this difference has caused the non-symmetric nature of the combined axial rail stress diagram over the deck transition piers when the axial rail stresses from the train loading are combined with the axial rail stresses from the thermal loading.

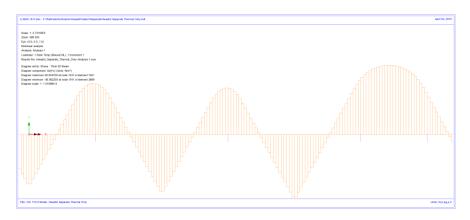


Figure 82: Zoomed Axial Stress In Rails Due To Thermal Effects Only

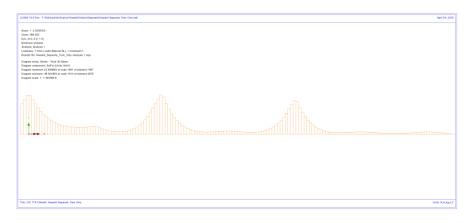


Figure 83: Zoomed Axial Stress In Rails Due To Braking Train Loads On Track 1

NOTE: When viewing this axial force diagram it should be recognised that while the first two decks (2*25m each) have identical geometry and pier/bearing properties, the first span segment of the first deck does not carry any of the braking train load and this is contributing to the difference in the behaviours observed over the piers.

Looking at the yield in the track/bridge interaction for this track, Figure 84, the reason for the differences in axial stress either side of the pier becomes clear as yielding has occurred to the left but not to the right of the deck transition pier for these first two decks.



Figure 84: Yield In Track/Bridge Interaction Due To Train Braking Load On Track 1

Looking now at the second track where the accelerating train is at the right-hand end of the structure, the interaction remains unloaded and so the rail axial stress observed is basically due to the bending of the bridge deck due to the action of the braking train load on the other track. Because there is no direct loading to the track then the axial stress in the rail displays a continuous variation over the span transition piers and therefore no reduction is observed in the combined diagram for this track.

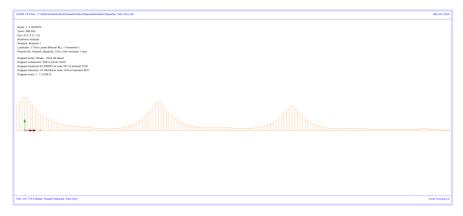


Figure 85: Zoomed Axial Force In Rails Due To Accelerating Train Loads On Track 2

Looking again at the yielding, Figure 86, the difference between this track and the one with the braking train becomes obvious as, without the action of any train load over the deck transition for this track, the yield is roughly symmetrical and occurring across the transition between decks – colour change indicates changing yield direction. This yield over the whole region of the deck transition is the whole reason why a smooth behaviour is observed in the rail stress in the second track as opposed to the first track that has the braking train load.

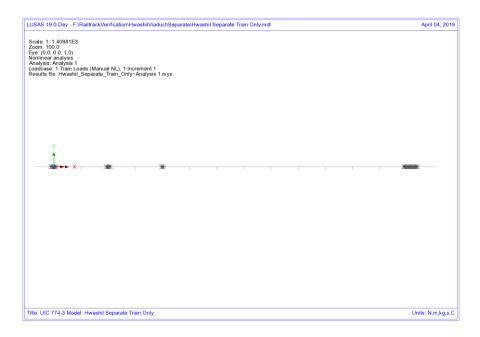


Figure 86: Yield In Track/Bridge Interaction Due To Train Acceleration Load On Track 2

Analysis of Combined Thermal and Rail Loading (One Step)

In this form of analysis a single nonlinear analysis is carried out where the thermal and rail loading are applied concurrently to the model. In terms of the track/bridge interaction, the resistance bilinear curves used in the modelling are determined by the positioning of the rail loading so that loaded properties are used where the rail loading is applied and unloaded properties everywhere else. As with the separate method highlighted above, this analysis ignores any initial straining of the track/bridge interaction under pure thermal loading and therefore assumes that the loaded resistance properties are active under the thermal loading over the extent of the train loading.

The results from the analysis are shown in the following figures and give the following results for the track peak compressive stresses:

Track 1:	85.61 N/mm ²
Track 2:	100.61 N/mm ²

NOTE: For this analysis the reduction in axial rail stress is not observed at the span discontinuities towards the left end of the structure.

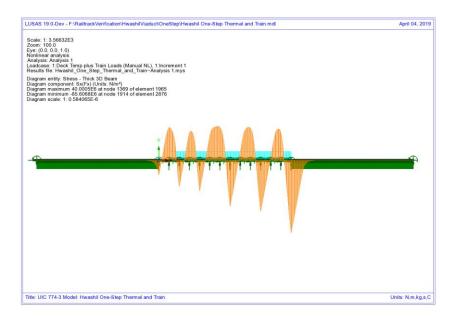


Figure 87: Axial Stress In Rails Due To Combined Thermal And Train Loads In Track 1 (One Step)

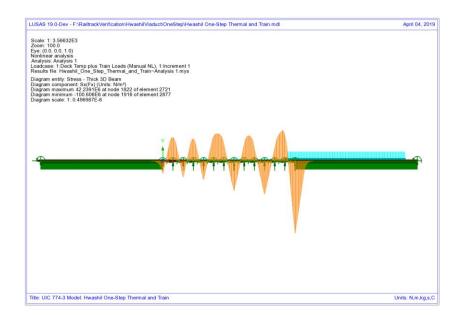


Figure 88: Axial Force In Rails Due To Combined Thermal And Train Loads In Track 2 (One Step)

Analysis of Combined Thermal and Rail Loading Taking Account of Effects of Material Change Under Rail Loading

The previous two analysis methods fail to take account of the train rail loading being applied to the rail when it has already undergone movement/stresses due to thermal effects alone. In this current form of analysis (implemented into LUSAS) the initial thermal effects are considered prior to the application of the train rail loading and the behaviour under this rail loading takes account of this history.

To illustrate the analysis, consider the following:

When the train is not on the track the stresses in the rails are governed purely by the thermal effects. For the Hwashil Viaduct the thermal effects due to the bridge only are considered and therefore the action of this causes the structure to move thus inducing relative movement between the track and the bridge and therefore an associated stress in the rail. For this condition the unloaded resistance properties apply across the whole extent of the track

As the train load arrives over a particular part of the bridge the initial relative movement of the track/bridge from the thermal effects remains and therefore the application of the train load changes the resistance state from unloaded to loaded without the loss of this initial rail stress caused by the relative movement

The train load causes increased slip of the interaction based on the loaded resistance with the end of the force-displacement curve for the unloaded resistance used as the starting point for the loaded resistance

If it was modelled, the departure of the train load would change the resistance state back to unloaded

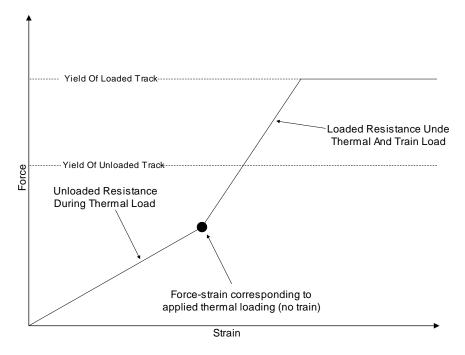


Figure 89: Representation of Transition From Unloaded To Loaded In LUSAS

The key is that the interaction resistance switches from unloaded to loaded the moment the rail load arrives thereby 'locking in' any initial movement that has occurred under the thermal loading until that rail load departs. The results from this form of analysis are shown in the following figures which give peak compressive rail stresses of:

Track 1 and 2 (Thermal Only):	46.06 N/mm ²
Track 1 (Thermal and Train):	79.06 N/mm ²
Track 2 (Thermal and Train):	92.60 N/mm ²

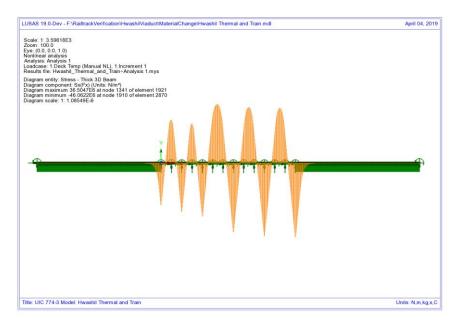


Figure 90: Axial Stress In Rails Due To Thermal Only

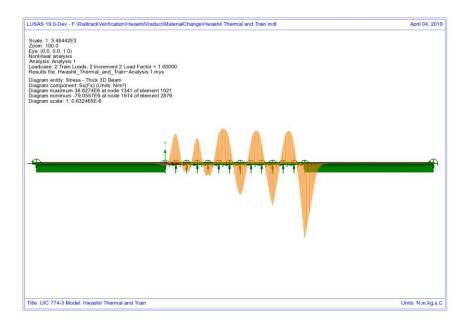


Figure 91: Axial Stress In Rails Due To Combined Thermal And Train Loads In Track 1

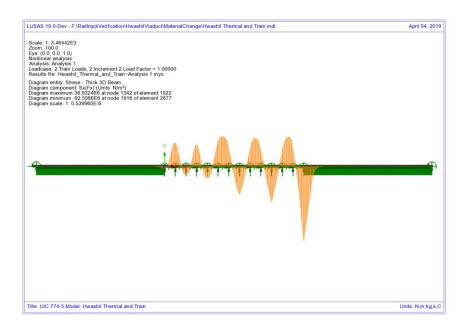


Figure 92: Axial Stress In Rails Due To Combined Thermal And Train Loads In Track 2

The analyses produced using this method can give a lower peak compressive stress in the rails than observed using the other approaches but agrees closely with the published test cases using rigorous methods in UIC774-3 as observed in the following sections for test E1-3 and H1-3.

Discussion

The peak compressive stresses in track/rail 2 which has the accelerating load and track/rail 1 that is subjected to the braking train show differences in the peak compressive stress in the rails based on the position of the train loads used in the analysis. As the loading and geometry of the models are identical the differences can only be associated with the track resistance modelling/behaviour. It has been noted previously above that the transition from unloaded resistance to loaded resistance is only incorporated into the LUSAS modelling so this track resistance is investigated by looking at the yield under the effects of the rail loading.

Looking first at the second track/rail that has the accelerating load, the yielding occurring from the three analyses are shown in the following figures. Comparing the yield layout for the LUSAS analysis (Figure 96) and the concurrent thermal/train loading analysis (Figure 95) shows that the amount of yielding of the interaction joints (ballast) at the right-hand abutment is similar but the yielding diminishes away from the accelerating locomotive at the front of the train which has only just entered the structure at the right-hand abutment in the LUSAS analysis whereas in the concurrent

loading analysis it is predicting large regions of yielded interaction joints. In the LUSAS analysis yielding may have previously occurred of unloaded material under thermal only loading but relieving of the forces in the unloaded interaction joints away from the accelerating train has caused them to return to elastic behaviour with a permanent deformation, hence the absence of indicated active yield flags.

Looking now at the separate analysis, the yield layout for the concurrent thermal/train analysis is comparable to the yield layout for the thermal effects alone (Figure 93). In the separate train loading analysis very little yielding is indicated as being associated with the accelerating train loading analysis (Figure 94). This is due to the accelerating train only just entering the bridge with the majority of the loads over the right approach embankment which are vertical not horizontal. The potential relieving effects of the train loading in this analysis are combined through a basic combination (unlike in the LUSAS material change method) but for this separate analysis the yield strength of both the unloaded and loaded materials are both counted so if both analyses yield at the same position (as is the case at the right-hand abutment and elsewhere) then it is possible that the interaction joints / ballast could be considered too strong – see below.

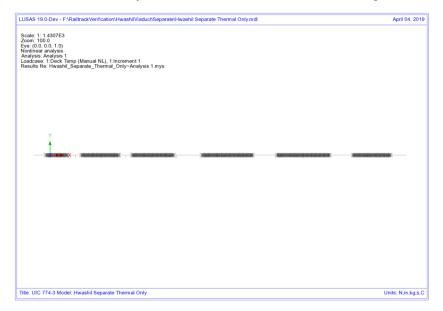


Figure 93: Track/Rail 2 Yield Due To Thermal Load On Track Alone

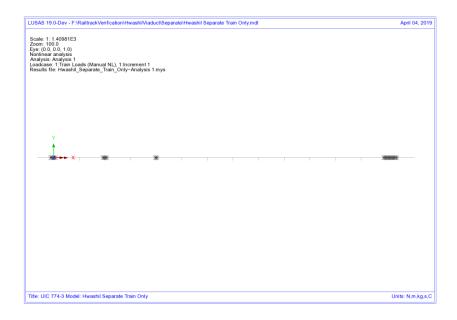


Figure 94: Track/Rail 2 Yield Due To Accelerating Train Loads On Track 2 – Separate Analysis

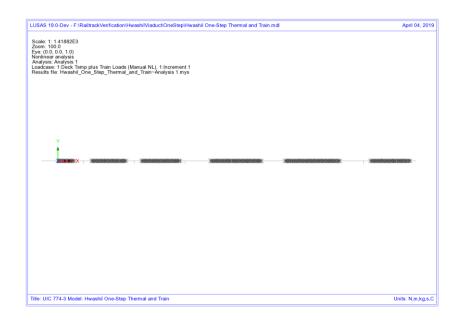


Figure 95: Track/Rail 2 Yield Due To Accelerating Train Loads On Track 2 - Thermal And Rail Applied Concurrently

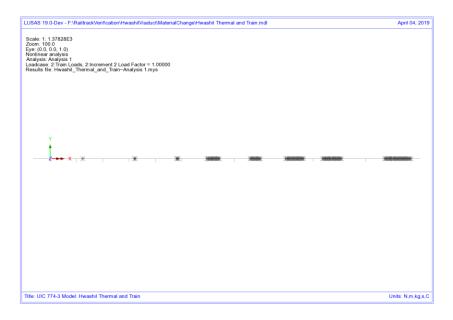


Figure 96: Track/Rail 2 Yield Due To Accelerating Train Load On Track 2 - LUSAS Combined Analysis

Looking at what is effectively happening in these analyses, Figure 97, the concurrent loading analysis uses the loaded resistance throughout the analysis and follows the loaded stiffness curve from the origin and potentially gives the location indicated on the plastic part of this curve as illustrated with a force in the interaction limited to the resistance of the loaded track. For the separate analysis, the thermal effects use the unloaded curve and the behaviour of this part of the analysis is limited by the resistance of the unloaded track. Under these conditions the analysis may give a location indicated by the 'Thermal Alone' point on the unloaded curve. Separate consideration of the train loading effectively places the origin of the loaded bilinear curve at this 'Thermal Alone' position and any loading could potentially give the location indicated by the 'Separate Train Load Added To Thermal' position. This could give an apparent increase in the resistance of the track and therefore increase rail stresses in the loaded track.

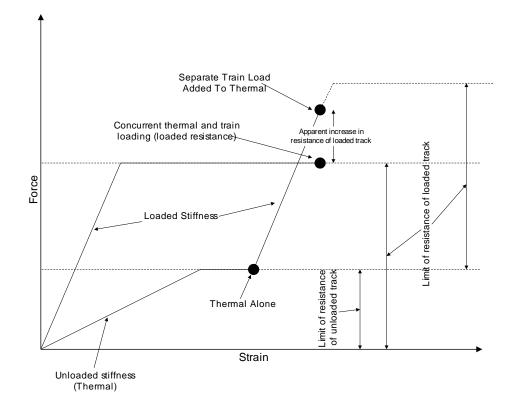


Figure 97: Illustration Of Behaviour Of Separate Analysis Vs. Concurrent Thermal And Rail Loading

Similar comparisons can be made between the separate analysis and the LUSAS analysis - Figure 98. While both of these effectively use the 'Thermal Alone' location as an origin for the loaded resistance curve, the key difference between the two approaches is that the LUSAS analysis enforces the track resistance at which plasticity occurs instead of allowing the potential for an apparent increase in the track resistance equal up to the unloaded plus the loaded track resistance.

These differences have affected the peak compressive rail stresses in the track subjected to accelerating train loads with all three analyses predicting stresses in the range of 92.6 to 103.7 N/mm².

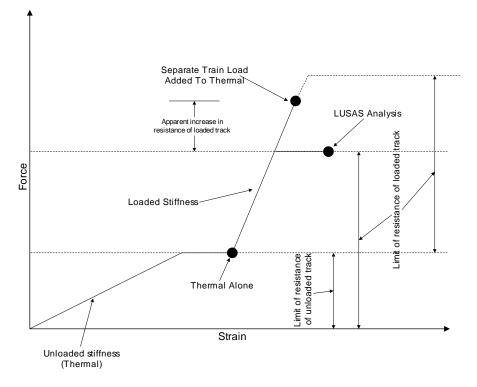


Figure 98: Illustration Of Behaviour Of Separate Analysis Vs. LUSAS Analysis

Looking now at the track/rail that has the braking train on it, the following figures show the same yield plots for this track/rail resistance. The immediate observation again is the different yield behaviour observed for the LUSAS analysis. Looking initially at the separate analysis and the concurrent thermal and rail loading analysis the yielding observed in the thermal alone for the separate analysis (Figure 99) shows close similarity to the yielding observed when the thermal and train loading are applied concurrently (Figure 101) – minimal yielding is observed under the action of the train load alone in the separate analysis (Figure 100).

Concentrating on the LUSAS analysis, the front of the braking train load is just over the right end of the structure and the carriages cover most of the remaining bridge. This has the effect, unlike the accelerating track, of changing nearly all of the resistance from unloaded to loaded for this track over the bridge and therefore the interaction is no longer under yield because the loaded resistance now governs plastic yield. The LUSAS analysis however does not display the possible apparent increase in the resistance of the track that can be observed with the separate analysis method. This means the track interaction around the front of the braking train resisting the movement of the rails cannot sustain the same level of loading and therefore yield to a larger extent than observed in the separate analysis, thereby reducing the compressive stress in the rails underneath the train – compare Figure 100 and Figure 102 where the yielding underneath the braking train is greater for the LUSAS analysis than in the separate rail load analysis.

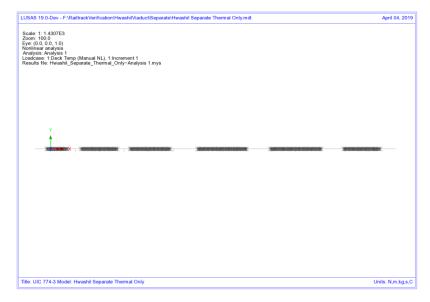


Figure 99: Track/Rail 1 Yield Due To Thermal Load On Track Alone

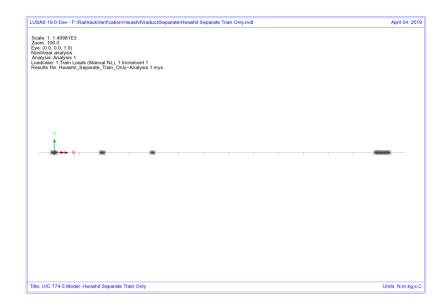


Figure 100: Track/Rail 1 Yield Due To Braking Train Loads On Track 1 – Separate Analysis

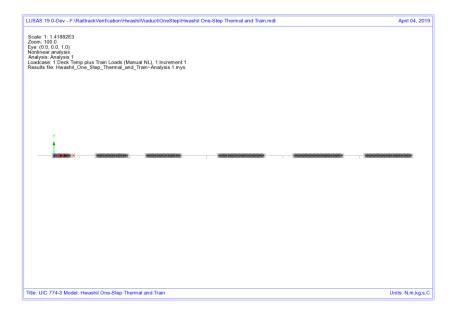
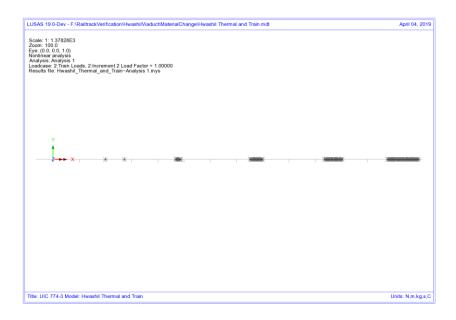
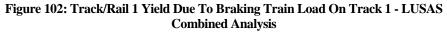


Figure 101: Track/Rail 1 Yield Due To Braking Train Loads On Track 1 - Thermal And Rail Applied Concurrently





Analysis of Combined Thermal and Rail Loading Taking Account of Effects of Material Change Under Rail Loading

Looking at the behaviour of the track interaction for the separate analysis we can plot the values of the force per metre length for the track subjected to the braking train loads. Figure 103 and Figure 104 show the forces per metre length for the thermal loading and the train braking loading for the separate analyses. Clearly, near the righthand abutment, the force per metre length under the thermal loading is equal to 40kN/m and due to the train loading is equal to 60kN/m. Combination of these two results means that the track interaction has mobilised 100kN/m in this region when it is actually only able to mobilise 60kN/m based on the loaded track resistance bilinear curve – the separate analysis method is giving an apparent increase in the loaded track resistance that can be mobilised before plastic yielding occurs. This apparent increase in the loaded track resistance has the consequence of allowing the rail stresses to increase beyond the value that would occur if the true loaded track resistance was used as in the LUSAS modelling where the track resistance is correctly limited to the loaded value of 60kN/m – Figure 105.

NOTE: This difference in the amount of track resistance that can be mobilised in the loaded condition is the main reason for the differences in the solutions obtained for the separate and LUSAS methods and demonstrates that the correct modelling of the interaction is critical to the solution.

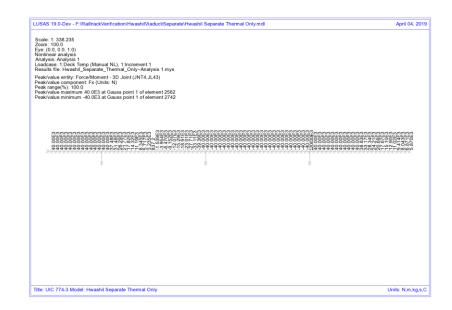


Figure 103: Force In Interaction At Right-Hand End Of Structure Where Peak Compressive Stresses Occur In The Rail - Track 1 – Separate Thermal Loading (N/m length)

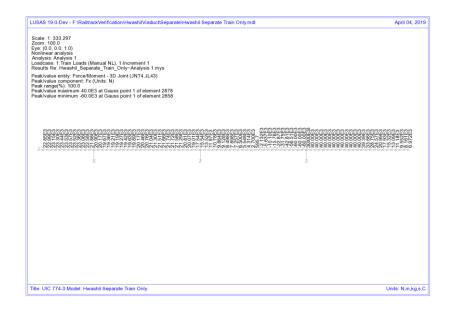


Figure 104: Force In Interaction At Right-Hand End Of Structure Where Peak Compressive Stresses Occur In The Rail - Track 1 - Separate Train Loading (N/m length)

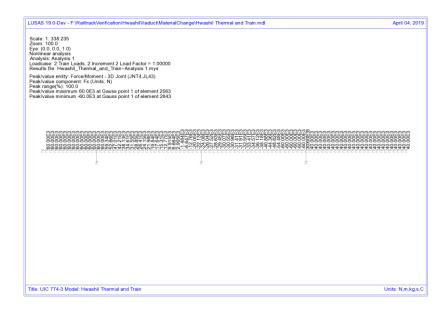


Figure 105: Force In Interaction At Right-Hand End Of Structure Where Peak Compressive Stresses Occur In The Rail - Track 1 – LUSAS Nonlinear (N/m length)

Revisit of UIC774-3 Test E1-3 Using the Separate and LUSAS Methods of Analysis

The standard UIC774-3 test E1-3 has been reanalysed using the following two approaches:

- **D** Separate analysis of thermal and rail loading effects
- LUSAS full nonlinear analysis

The results of these two analyses are presented in the following sections and then discussed briefly.

Separate Analyses

The analysis of the thermal effects due to the temperature in the bridge and rail are presented in the following figure. These two thermal effects give a peak compressive rail stress of 155.63 N/mm² which compares well with the code of practice value of 156.67 N/mm².

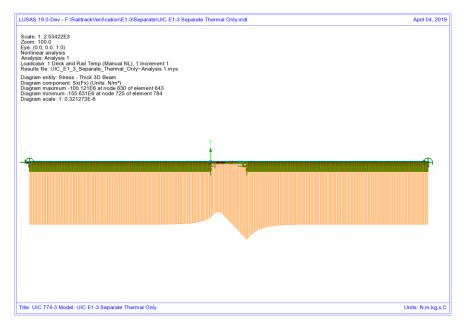


Figure 106: Axial Stress In Rails Due To Temperature In Bridge And Rail

To determine the worst location of the train load for compressive rail stresses the bridge has been analysed with the rail loading at 31 separate locations (starting from the left abutment of the bridge and finishing 90m from the right abutment of the bridge – train moving from left to right) and these results enveloped. The results of this

analysis are presented in the following figure which give a peak compressive rail stress of 40.64 $\rm N/mm^2.$

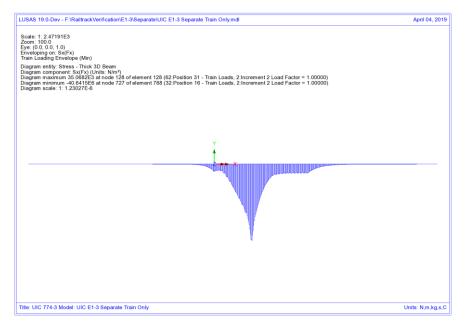


Figure 107: Envelope Of Axial Stress In Rails Due To Rail Loading

Manual combination of the peaks would give a peak compressive rail stress of 196.27 N/mm^2 (ignoring locations of the peaks) and combination of the results in LUSAS gives the same peak compressive rail stress of 196.27 N/mm^2 which occurs over the transition from the structure to the embankment at the right-hand abutment.

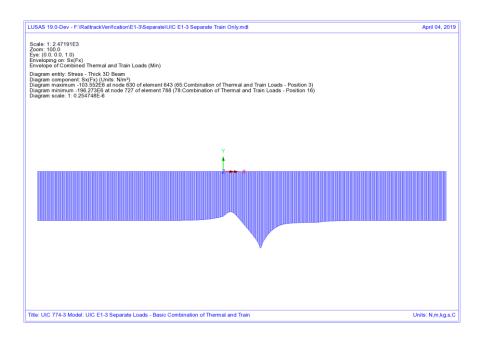


Figure 108: Axial Stress In Rails Due To Combined Temperature And Rail Loading

Comparison of these results with the UIC774-3 code of practice test results shows that the result compares well with the 190.07 N/mm² compressive rail stress from the simplified analysis in the test case (which is based on evaluating the effect of each part of the loading separately).

LUSAS Nonlinear Analysis

The UIC774-3 E1-3 test case has been reanalysed using the LUSAS rail option and gives the following peak compressive rail stress for the thermal loading alone and the combined thermal and rail loading:

Thermal:	155.63 N/mm ²	
Thermal & Rail:193.06 N/mm ²		

Comparison of the results shows that the rail stresses are in excellent agreement for both parts of the analysis with the peak compressive rail stress of the combined thermal and train loading having a percentage error of 5.8% when compared against the target rigorous solution of 182.4 N/mm².

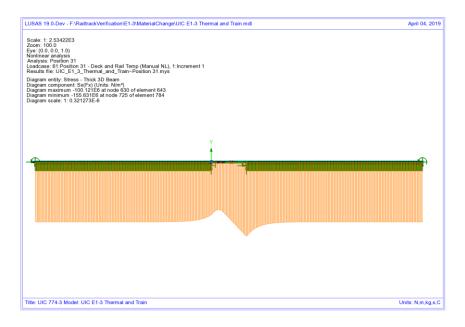
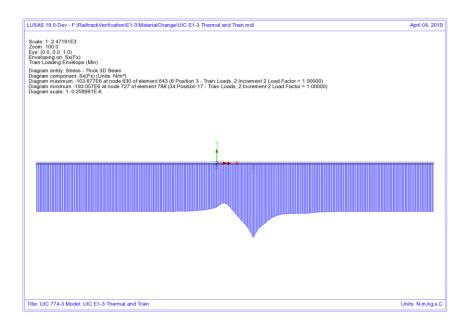
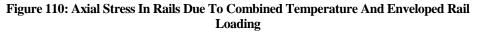


Figure 109: Axial Stress In Rails Due To Temperature In Bridge And Rail





Discussion

For this test case the difference in the results due to the track resistance modelling between the two methods is minimal. Combining the results of two nonlinear analysis, while invalid, gives almost identical results to the LUSAS analysis which correctly represents the transition from unloaded to loaded resistance on arrival of the train load. The train load position that gives the worst compressive stress in the rail does however differ slightly between the two analyses with the separate analysis giving a train front position of 75m from the left abutment of the bridge and the LUSAS combined analysis giving a train front position of 80m from the left abutment of the bridge.

Looking at the yield behaviour it becomes clear why the two methods agree so closely for this UIC774-3 standard test case and not for the Hwashil Viaduct. For both analyses, the rail stresses and interaction yield over the single span bridge due to thermal loading are identical – Figure 111. On consideration of the train loading, the right-hand end of the structure (roller bearing) where the peak compressive rail stresses are observed shows no sign of yield with yield only occurring over the left end and embankment – Figure 112 and Figure 113. This indicates that the separate analysis, while invalid due to the linear combination of two nonlinear analyses, is giving the correct result and this only occurs because the interaction over the structure at this location is nowhere near yield.

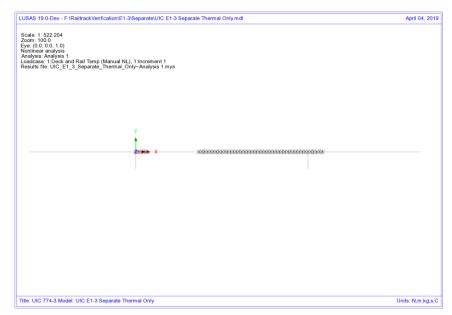


Figure 111: Yield Layout For Thermal Loading Only

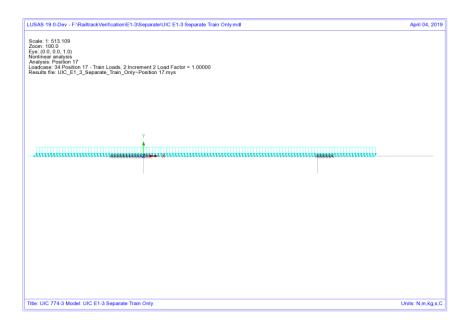
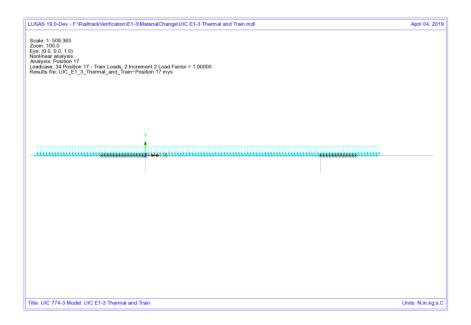
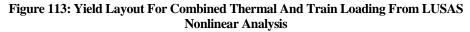


Figure 112: Yield Layout For Train Loading Only From Separate Analysis





The following two plots show the forces in the interaction joints for the thermal and train loads from the separate analysis at the transition of the right-hand of the deck to the embankment. The thermal loading has caused yielding of the unloaded track interaction with a value of 20 kN/m in accordance with the unloaded resistance but the train loads have only induced up to about 25.6 kN/m over the structure. Combining these two results means that the total force per unit length for the separate analysis is 45.6 kN/m which is comparable to the LUSAS nonlinear solution of 40.5 kN/m – see Figure 116. Because the interaction is well below yield for the loaded interaction resistance of 60 kN/m the two solution method effectively have identical solutions and their behaviour can be visualised in Figure 117.

If, however, the train loading had induced interaction forces in the region of 40 kN/m (taking account of the track resistance already mobilised by the thermal loading) instead of the observed 25.6 kN/m then significant differences could be observed in the two analysis methods as the separate method would still allow a further 20 kN/m track resistance to be mobilised before the onset of plastic yielding and the separate analysis would potentially over predict the rail stresses occurring. This potentially means that...

...even though a computer program is validated against the standard test cases in the UIC774-3 code of practice, it may be predicting excessive rail stresses if it does not correctly take account of the loaded track resistance that can be mobilised.

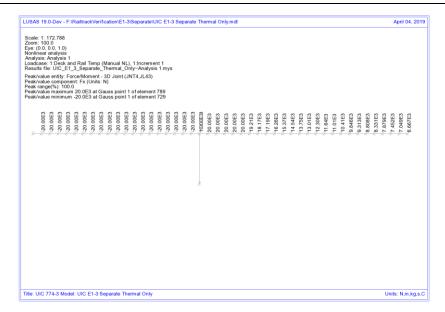


Figure 114: Force Per Metre Length In Interaction From Thermal Loading - Separate Analysis

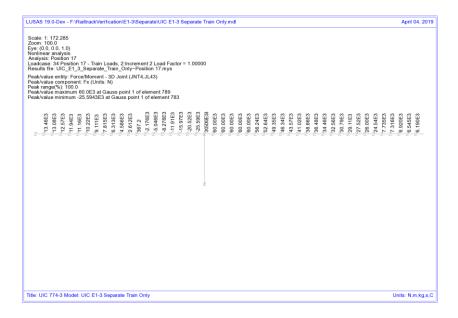


Figure 115: Force Per Metre Length In Interaction From Train Loading - Separate Analysis

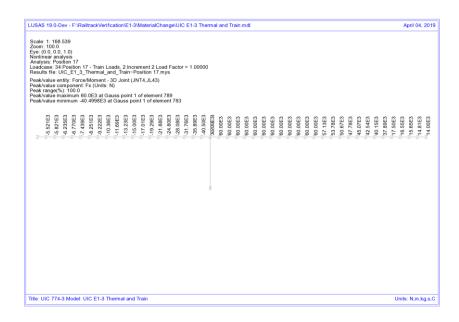


Figure 116: Force Per Metre Length In Interaction From Combined Loading - LUSAS Analysis

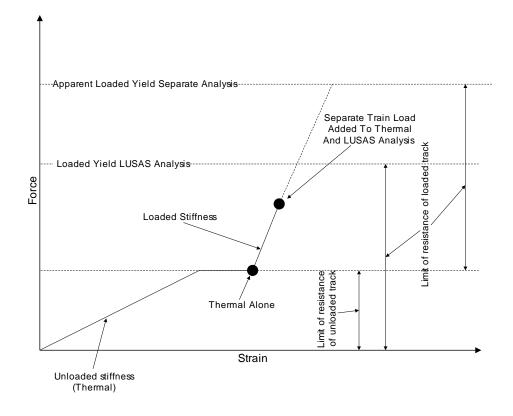


Figure 117: Illustration Of Behvaiour For UIC774-3 Standard Test E1-3 For Separate And LUSAS Analyses

Revisit of UIC774-3 Test H1-3 Using the Separate and LUSAS Methods of Analysis

The previous test case (E1-3) is one of the key test cases that must be matched for computer programs carrying out this form of analysis with the results for both the separate method and the LUSAS method being in close agreement to the results required. The deck type for this test is however a concrete slab underlain by I-section steel beams which does not compare with the deck being used for Hwashil Viaduct. For this reason the H1-3 test is also revisited and solved using the two methods of analysis.

Separate Analyses

The analysis of the thermal effects due to the temperature in the bridge and rail are presented in the following figure. These two thermal effects give a peak compressive rail stress of 167.77 N/mm² which compares very well with the code of practice value of 169.14 N/mm².

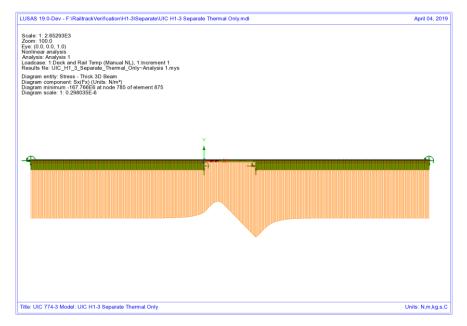


Figure 118: Axial Stress In Rails Due To Temperature In Bridge And Rail

To determine the worst location of the train load for compressive rail stresses the bridge has been analysed with the rail loading at 37 separate locations (starting from the left abutment of the bridge and finishing 90m from the right abutment of the bridge – train moving from left to right) and these results enveloped. The results of this analysis are presented in the following figure which give a peak compressive rail stress of 29.09 N/mm².

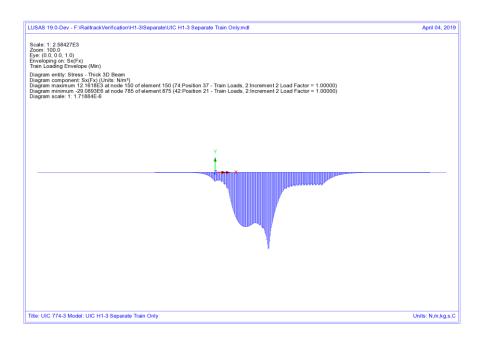


Figure 119: Envelope Of Axial Stress In Rails Due To Rail Loading

Manual combination of the peaks would give a peak compressive rail stress of 196.86 N/mm^2 (ignoring locations of the peaks) and combination of the results in LUSAS gives 196.86 N/mm^2 which occurs over the transition from the structure to the embankment at the right-hand abutment.

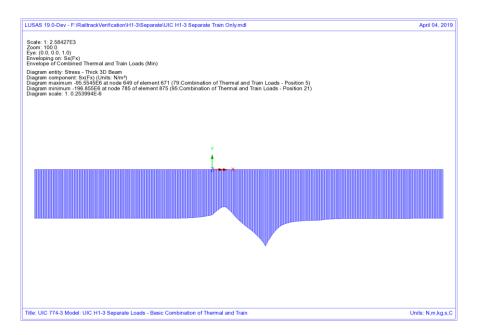


Figure 120: Axial Stress In Rails Due To Combined Temperature And Rail Loading

Comparison of these results with the UIC774-3 code of practice test results shows that the result compares well with the 211.37 N/mm² compressive rail stress from the simplified and the 188.23 N/mm² compressive rail stress from the rigorous analysis in the test case.

LUSAS Nonlinear Analysis

The UIC774-3 H1-3 test case has been reanalysed using the LUSAS rail option and gives the following peak compressive rail stress for the thermal loading alone and the combined thermal and rail loading:

Thermal:	167.77 N/mm ²	
Thermal & I	Rail:195.91 N/mm ²	

Comparison of the results shows that the rail stresses are in excellent agreement for both parts of the analysis with the peak compressive rail stress of the combined thermal and train loading having a percentage error of 4.1% when compared against the target rigorous solution of 188.23 N/mm².

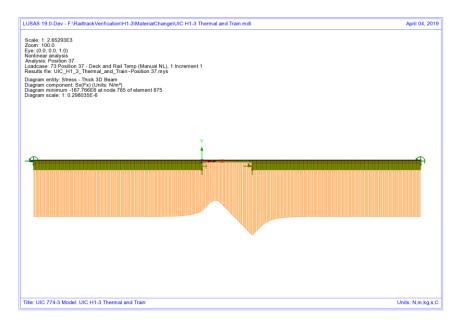
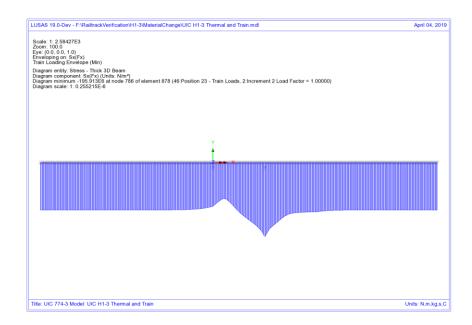


Figure 121: Axial Stress In Rails Due To Temperature In Bridge And Rail





Discussion

As with the previous E1-3 test case, the difference in the results due to the track resistance modelling between the two methods is minimal. Combining the results of two nonlinear analysis, while invalid, gives almost identical results to the LUSAS analysis which correctly represents the transition from unloaded to loaded resistance on arrival of the train load. The train load position that gives the worst compressive stress in the rail does however differ slightly between the two analyses with the separate analysis giving a train front position of 100m from the left abutment of the bridge and the LUSAS combined analysis giving a train front position of 110m from the left abutment of the bridge.

Referring back to test E1-3, similar plots can be generated for the yield and forces in the interaction. These, as with the E1-3 test, show that the train loading is not bringing the force per metre length in the interaction close the loaded yield resistance of 60 kN/m and therefore the separate analysis and LUSAS analysis methods agree even though the separate method potentially allows more track resistance to be mobilised than is allowed when the thermal and rail results are combined.

Separate:	27.6 kN/m
LUSAS:	26.1 kN/m

USAS 19.0-Dev - F\RailtrackVerification\H1-3\Separate\UIC H1-3 Separate Thermal Only.mdl	April 04, 20
Scale: 1: 265 293 Zoom: 100.0 Kontinear analysis Analysis: Analysis Loadcase: 1: Deck and Rail Temp (Manual NL), 1:Increment 1 Results file: ULC_H1_3_Separate_Thermal_Only-Analysis 1.mys	
Paek/value ently: Force/Moment - 3D Joint (JNT4,JL43) Peak range(%): 1000 Peak range(%): 1000 Peak/value maximum 20.0E3 at Gauss point 1 of element 879 Peak/value minimum -20.0E3 at Gauss point 1 of element 765	
200055 20	8.475E3
Ż	
itle: UIC 774-3 Model: UIC H1-3 Separate Thermal Only Un	its: N,m,kg

Figure 123: Force Per Metre Length In Interaction From Thermal Loading - Separate Analysis

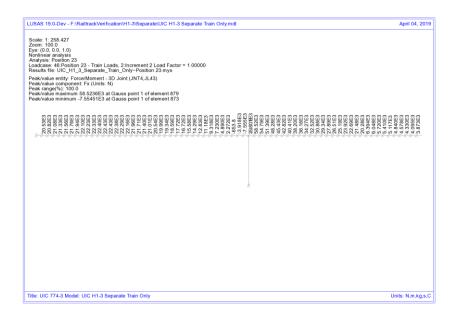


Figure 124: Force Per Metre Length In Interaction From Train Loading - Separate Analysis

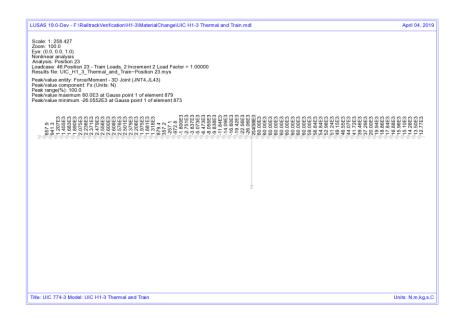


Figure 125: Force Per Metre Length In Interaction From Combined Loading - LUSAS Analysis

Conclusions

Three solution methods for carrying out the UIC track/bridge interaction analyses have been investigated and differences observed in the assumed behaviour and results highlighted. The key observations were as follows:

Separate Thermal and Rail Loading Analysis

- Correct unloaded track resistance used for thermal effects across whole model
- □ Correct yielding of unloaded ballast/frozen ballast-no ballast track under thermal effects
- □ <u>Incorrect</u> yielding of loaded ballast/frozen ballast-no ballast track assuming that thermal effects are present, only correct if there are no thermal effects
- □ Invalid combination of two nonlinear analyses results gives apparent increase in the resistance of the track due to stresses in ballast/frozen ballast-no ballast track from the unloaded thermal effects being ignored in the ultimate yield of the loaded analysis to correctly model the reduction of the resistance of the track before yielding occurs under loaded conditions, the yield resistance for the loaded condition should be reduced by the amount of resistance already mobilised due to the thermal effects
- □ Separate analysis ignores the movement that has already occurred under the thermal effects when the load from the train acts on the rails

Concurrent Thermal and Rail Loading Analysis

- □ <u>Incorrect</u> loaded track resistance used for thermal effects under location of train loads
- □ <u>Incorrect</u> yielding of ballast/frozen ballast-no ballast track under thermal effects as loaded track resistance used
- Correct track resistance for yielding under the train loading
- □ Movement due to thermal effects alone only approximated

LUSAS Nonlinear Thermal and Rail Analysis with Material Change

- □ Correct unloaded track resistance used for thermal effects across whole model
- □ Correct yielding of unloaded ballast/frozen ballast-no ballast track under thermal effects
- Correct yielding of loaded ballast/frozen ballast-no ballast track under action of combined thermal and train loading effects as track resistance correctly modelled (yield occurs at the correct loading – no apparent increase in the yield value)
- □ Instantaneous change from unloaded to loaded track resistance correctly takes account of movement that has already occurred under thermal effects alone

Referring back to Figure 97 and Figure 98, the key issue with the separate analysis approach is the ability for the track resistance to be overestimated by the combination of the two nonlinear analyses and potentially cause the rail stresses to be overestimated. In the concurrent loading and LUSAS rail option analyses the limit of track resistance is correctly modelled as the value determined from the loaded bilinear curve and therefore this potentially leads to reduced rail stresses observed in the analyses. As the initial movement under pure thermal loading in the concurrent analysis uses the loaded track resistance this will give different results to the LUSAS rail option analysis. Referring back to the Hwashil Viaduct analyses, the rail stresses observed for the three analysis types are:

	Separate Analysis Of Thermal And Train Loading	Concurrent Thermal And Train Loading	LUSAS Nonlinear Thermal And Train Loading With Material Change
Track 1 (Braking)	94.99	85.61	79.06
Track 2 (Accelerating)	103.66	100.61	92.60

Table 2: Comparison Of Peak Compressive Rail Stresses (in N/mm²) For Different Analysis Methods

Comparison of the results for the separate and LUSAS analyses shows that the peak compressive stress for the separate analysis is 1.2 times that of the LUSAS analysis for track 1 and 1.12 times for track 2. It should be noted however that the separate analysis could be giving an apparent increase in track resistance of up to 1.6 times that of the loaded track due to the combination of the nonlinear results. The concurrent analysis gave results that are between the separate and LUSAS analysis as expected since the correct limit of loaded track resistance is modelled even though the thermal effects are only approximated.

One overall conclusion is obvious from these test case analyses and discussions made in this appendix:

When a combined thermal and train loading from a separate analysis gives interaction forces that exceed the stated yield resistance then the separate analysis method will potentially over predict the rail stresses unless the loaded track yield surface is reduced by the mobilised track resistance over the extent of the train loading.

References

U1 UIC Code 774-3 R. Track/bridge Interaction. Recommendations for Calculations (2001) Union Internationale des Chemins de fer, Paris, France

Appendix B: Definition of Complex Trainset Configurations

Introduction

Although some trainsets can be simplified with a few uniformly distributed loads (UDLs) to describe the loading pattern, many trainsets are more complex than this and require the definition of multiple components to describe the overall pattern of loading. Some of these trainset configurations require the modelling of point loads, Uniformly Distributed Loads (UDLs) or the combination of the two. This appendix includes some examples of the definition of more complex trainset configurations which require such loading patterns.

Definition of Trainset Configurations With UDLs Alone

The UDL loading allows the definition of trainset configurations where the load is spread over lengths of the track as illustrated by the example shown in Figure 126. In this configuration the vertical load varies along the length of the trainset and the acceleration / traction load acts only over the length of the locomotive(s). In the definition the train is accelerating to the left for any structure model it is applied to with the origin of the trainset loading defined at the left-hand extent of the configuration. Any number of UDLs can be used for the definition of the trainsets in the **Loading** worksheet of the input Microsoft Excel spreadsheet to allow more complex configurations to be defined.

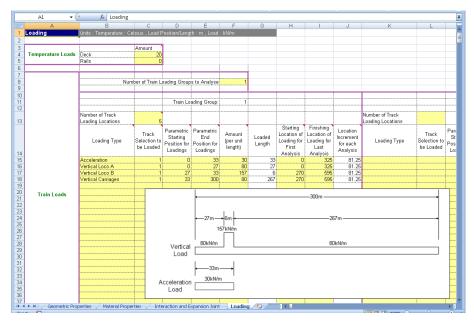


Figure 126: More Complex Train Loading Definition in Spreadsheet

Additional simple examples were illustrated in Figure 34 on page 31 showing the types of loading configurations that can be defined.

EuroCode Load Model SW/0 Loading Configuration

The SW/0 vertical loading pattern is shown in Figure 127 which has two separated UDLs. In addition, Note 1 of Clause 6.5.3 'Actions due to traction and braking' within BS EN 1991-2:2003 states that 'For Load Models SW/0 and SW/2 traction and braking forces need only be applied to those parts of the structure which are loaded according to Figure 6.2 and Table 6.1' where this figure is equivalent to Figure 127 below. The definition of the SW/0 trainset configuration will therefore be described below according to these conditions.

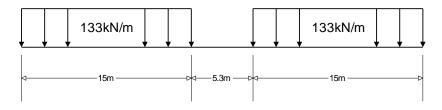


Figure 127: EuroCode Load Model SW/0 Train Vertical Load Pattern

For trainset loading configurations such as EuroCode SW/0 (and also SW/2) it is often best (but not essential) to define the origin of the trainset configuration at the centre of the load pattern.

Considering first the vertical loading, if we take the centre of the load configuration as the origin we can define the UDLs as follows:

Loading Type	Left Coordinate (m)	Right Coordinate (m)	Amount per Unit Length (kN/m)	
Vertical SW/0 (Left UDL)	-17.65	-2.65	133.0	
Vertical SW/0 (Right UDL)	+2.65	+17.65	133.0	

Table 3: SW/0 Parametric Vertical Loading Definition

As stated in BS EN 1991-2:2003 Clause 6.5.3, the braking load from the SW/0 trainset should be defined as a UDL over the parts that are loaded and with a value of 20kN/m (limited to 6000kN total load) in the direction of travel. Assuming that we are defining the SW/0 trainset travelling to the right in the Rail Track Analysis model the loading configuration will be as illustrated in Figure 128 with the loading origin at the centre.

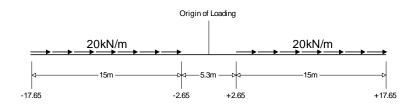


Figure 128: EuroCode SW/0 Train Braking Load Pattern

The total braking load in accordance with the figure above will be only 600kN which is below the limit, therefore the braking load requires no adjustment and can be defined as follows:

Loading Type	Left Coordinate (m)	Right Coordinate (m)	Amount per Unit Length (kN/m)	
Braking SW/0 (Left UDL)	-17.65	-2.65	20.0	
Braking SW/0 (Right UDL)	+2.65	+17.65	20.0	

Table 4: SW/0 Parametric Braking L	oading Definition
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The overall SW/0 trainset loading definition can therefore be input into the **Loading** worksheet of the Microsoft Excel spreadsheet as shown in the following figure and the loading positions defined as required.

	А	В	С	D	E	F	G	Н		J	
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_			0								
	*		Amount								
	Temperature Loads	Deck	30								
		Rails	50								
		Numl	per of Train L	pading Group	s to Analyse	3					
כ											
1				Train Lo	ading Group:	1					
2											
		Number of Track									Numbe
3		Loading Locations	5								Loadin
				Parametric	Parametric	1		Starting	Finishing	Location	
			Track	Starting	End	Amount	Loaded	Location of		Increment	
		Loading Type	Selection to	Position for		(per unit	Length	Loading for	Loading for	for each	L
			be Loaded	Loadings	Loadings	length)	Length	First	Last	Analysis	
4								Analysis	Analysis		
5		Vertical SVV/D (Left UDL)	1			133	15	82.35		38.825	
6		Braking SW/0 (Left UDL)	1		-2.65	20	15	82.35	237.65	38.825	
7		Vertical SW/0 (Right UD	1			133	15	82.35	237.65	38.825	
8		Braking SW/0 (Right UD	1	2.65	17.65	20	15	82.35	237.65	38.825	Brakin
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0	Train Loads										
1	Train Loado										
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Figure 129: Complete SW/0 Trainset Configuration

Definition of Trainset Configurations With Concentrated Loads

Concentrated loads can be approximated in the Rail Track Analysis tool by defining a UDL which acts only over a small length of track. With the 1m to 2m element sizes typically used for the modelling this approach is sufficiently accurate for the representation of these load types (a contact length that is 5 to 10% of the element length or smaller should be suitable for most applications).

EuroCode Load Model 71 Loading Configuration

The Load Model 71 vertical loading pattern is shown in Figure 130. This trainset load pattern has two UDLs either side and four concentrated loads in the centre. BS EN 1992-2:2003 Clause 6.5.3 'Actions due to traction and braking' describes the

longitudinal braking and traction loads that should be considered with Load Model 71 but these are not considered here. For this example we will only consider the definition of the four 250kN concentrated loads shown in Figure 131 (with the origin of the loading taken at the centre) and how these can be approximated within the Rail Track Analysis tool.

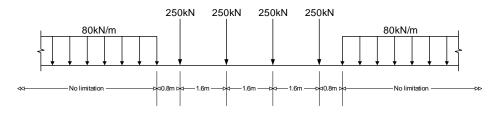


Figure 130: EuroCode Load Model 71 Train Vertical Load Pattern

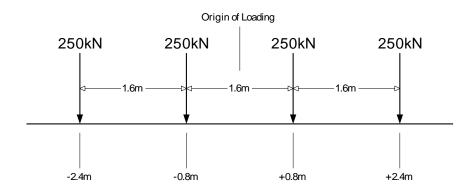


Figure 131: Load Model 71 Concentrated Loads Only

Although the Rail Track Analysis tool only allows the input of trainset loading through UDLs these concentrated loads can be defined by recognising that for the size of elements used in the model the concentrated load is equivalent to a UDL over a very small length. If our structural modelling has element lengths of 1.0 to 2.0m then the setting of the contact length as 1 to 5% of this length (0.01 to 0.05m for 1.0m and 0.02 to 0.1m for 2.0m elements) should be sufficient to define the equivalent UDL to the concentrated load for a good number of structural configurations. Obviously the smaller the contact length the closer the equivalent UDL comes to a concentrated load.



Note. The choice of the contact length to be used to define the equivalent UDL to a concentrated load must be decided by the user based on the configuration of the model and the element lengths used for the meshing of that model. The illustration here

should be viewed as a guide on how to incorporate concentrated loads with a trainset definition and not as the de facto contact length to be used for all circumstances.

Taking the contact length for this example as 0.01m the equivalent UDLs for the modelling will therefore have a value of:

UDL = Conc.Load/ContactLength = 250 kN/0.01m = 25000 kN/m

The definition of the four concentrated loads of Load Model 71 now becomes the four UDLs indicated in Figure 132.

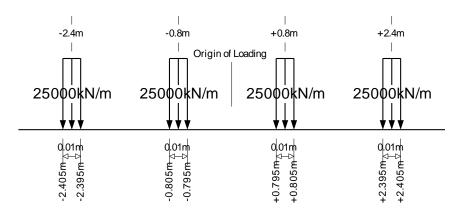


Figure 132: Load Model 71 Equivalent UDLs to Concentrated Loads

This UDL definition of the four concentrated loads of Load Model 71 can now be defined in the **Loading** worksheet of the input Microsoft Excel spreadsheet as illustrated in Figure 133.

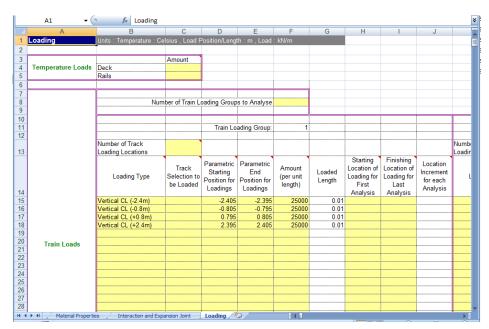


Figure 133: Sample Loading Definition for Load Model 71 Concentrated Loads

EuroCode Load Model HSLM-A Loading Configuration

The previous example illustrating the definition of the four concentrated loads of Load Model 71 can easily be defined manually. The definition of more complex trainset configurations consisting of numerous concentrated loads (and possibly UDLs) cannot be defined easily without the risk of error. For these types of loading configurations it is advisable to define the loading using a more automated approach. This will be demonstrated using the VBScripting capabilities of LUSAS Modeller for Load Type HSLM-A.

The HSLM-A Load Model representing a universal train, Figure 134, consists of multiple concentrated loads with the magnitude and configuration which is dependent upon the universal train type (A1 to A10).

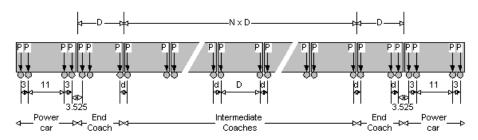




Figure 135 shows a HSLM-A1 trainset (with braking loads) which has been defined in the **Loading** worksheet using the equivalent UDL approach for the concentrated loads. The input just for the single HSLM-A1 braking trainset requires 51 rows of data input to define all of the axle loads and the braking load.

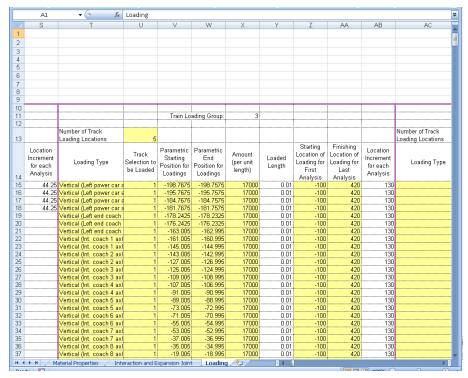


Figure 135: HSLM-A1 Trainset Defined In Loading Worksheet

It would take some time (and be prone to errors) to manually input all of the equivalent UDLs for the concentrated loads illustrated above for the HSLM-A trainset configuration. These loads should therefore be defined through an automated method such as another Microsoft Excel spreadsheet which defines the required data or by using the VBScript capabilities of LUSAS Modeller to parametrically define the trainset loads. Such a VBScript has been written as a demonstration for these HSLM-A trainset configurations.



Note. The VBScript included within this appendix was used to generate the data used in the worked example. The implementation has a number of assumptions which are detailed below.

The HSLM-A trainset definition VBScript is written based on the following assumptions (code is listed at the end of this appendix and is also available from the User Area on the LUSAS website):

- The braking trainset load definition assumes that the HSLM-A train is moving from left to right, the accelerating trainset load definition assumes that the HSLM-A train is moving from right to left (these can be changed by simply reversing the sign of the longitudinal loading values)
- Traction loads are applied as a UDL between the front and back axles of each of the power cars only. If the maximum load of 1000kN stated in Clause 6.5.3 of BS EN 1991-2:2003 is exceeded the loading is factored to ensure only 1000kN is defined
- Braking loads are applied as a UDL over the whole length of the trainset between the first and last axles. If the maximum load of 6000kN stated in Clause 6.5.3 of BS EN 1991-2:2003 is exceeded the loading is factored to ensure only 6000kN is defined
- The point loads are defined as equivalent UDLs using a user defined contact length (default = 0.01m)
- The origin of the HSLM-A trainset is defined at the centre of the trainset configuration when specifying the locations for the trainset across the embankments and structure
- The units are kN and m in accordance with the input requirements of the Rail Track Analysis tool.

The VBScript is run as follows:

- 1) Run the "Define_HSLM-A_for_RTA.vbs" VBScript
- 2) Enter the HSLM-A universal train ID (1 to 10) as shown below:

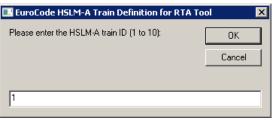


Figure 136: Input of the HSLM-A Train Configuration ID

3) Enter the contact length for the equivalent UDLs to represent the axle concentrated loads (in m):

ool 🛛 🗙
OK
Cancel

Figure 137: Input of the Contact Length for the UDLs Equivalent to the Concentrated Loads

4) Enter the filename for the generated TAB delimited trainset loading definition (with the *.prn extension):

🔜 EuroCode HSLM-A Train Definition for RTA 🛾	Tool 🛛 🔀
Please enter the file name for the generated train loading (with ".pm extension):	OK Cancel
HSLM-A1.pm	

Figure 138: Input of the Filename for the Output of the HSLM-A Train Configuration

On clicking OK the VBScript will now process the HSLM-A loading and generate a TAB delimited text file defining all of the loading for a braking train and an accelerating train as indicated in Figure 139 and Figure 140 (for a HSLM-A1 trainset with 0.01m contact length for the equivalent UDLs).

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	tical and braking loads for the braking train are defined first, followed by the vertical and	
	I loads for the accelerating train.	
	mporting into Microsoft Excel the appropriate loads for the analysis being considered can be co	pied
	ted into the input spreadsheet.	-
5		
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Figure 139: Output for a HSLM-A1 Trainset Configuration (1 of 2)

<u> </u>	Comparing the second se Second second se	pad++
	search view bicoung cangoge security had on cut ringing window :	
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HSL	HSLM-A1.pm 🔀	
99	9 Vertical (Int. coach 11 axle 2) TrackID 34.995 35.005 1	17000
100	0 Vertical (Int. coach 12 axle 1) TrackID 36.995 37.005 1	17000
101	1 Vertical (Int. coach 12 axle 2) TrackID 52.995 53.005 1	.7000
102	2 Vertical (Int. coach 13 axle 1) TrackID 54.995 55.005 1	.7000
103	3 Vertical (Int. coach 13 axle 2) TrackID 70.995 71.005 1	.7000
104		.7000
105	5 Vertical (Int. coach 14 axle 2) TrackID 88.995 89.005 1	.7000
106		
107	7 Vertical (Int. coach 15 axle 2) TrackID 106.995 107.005 1	.7000
108	8 Vertical (Int. coach 16 axle 1) TrackID 108.995 109.005 1	.7000
.09	9 Vertical (Int. coach 16 axle 2) TrackID 124.995 125.005 1	.7000
.10	0 Vertical (Int. coach 17 axle 1) TrackID 126.995 127.005 1	.7000
11		
12		
13	3 Vertical (Int. coach 18 axle 2) TrackID 160.995 161.005 1	.7000
.14		05 17000
.15	5 Vertical (Right end coach axle 2) TrackID 176.2325 1	176.2425 17000
.16	6 Vertical (Right end coach axle 3) TrackID 178.2325 1	178.2425 17000
.17	7 Vertical (Right power car axle 1) TrackID 181.7575 1	181.7675 17000
.18	8 Vertical (Right power car axle 2) TrackID 184.7575 1	184.7675 17000
.19	9 Vertical (Right power car axle 3) TrackID 195.7575 1	195.7675 17000
.20	0 Vertical (Right power car axle 4) TrackID 198.7575 1	198.7675 17000
21	1 Traction (Left power car) TrackID -198.7625 -181.7625	29.4117647058824
.22	2 Traction (Right power car) TrackID 181.7625 198.7625	29.4117647058824
23	3	
24	4 Traction load UDL has been factored as total load over th	e two 17 m power cars is 1122 kN (> 1000 kN limit
	for default UDL)	
125	5 Traction load UDL reduced to = 29.4117647058824 kN/m	
26	6	
_	al text file length : 7615 lines : 126 Ln : 1 Col : 1 Sel :	0 0 Dos\Windows ANSI as UTF-8 INS

Figure 140: Output for a HSLM-A1 Trainset Configurations (2 of 2)

To use this trainset loading within the **Loading** worksheet of the input Microsoft Excel spreadsheet you should initially have the input spreadsheet which has been edited to represent the structure loaded within Microsoft Excel. To transfer this data defined by the VBScript into the worksheet:

1) Import the TAB delimited file generated above into Microsoft Excel

2) Highlight the braking or accelerating/traction loading to be copied (only the rows defining the vertical and braking/traction loading) and choose Copy – below we are copying the braking trainset

	∫x Vertic	(0				1Z	
A	В	C	D	E	F	G	Н		J	K	L
This TAB delimited file defines							ositive (to f	the right) (direction i	n the RTA i	model
and an accelerating train travel	ing in the r	negative (to) the left) di	rection in the	RTA mod	⊇l.					
The vertical and braking loads f	or the brak	ing train are	e defined fi	rst, followed	by the ver	ical and tr	raction loa	ds for the a	acceleratir	ng train.	
After importing into Microsoft B	xcel the ap	opropriate l	oads for the	e analysis beir	ng conside	red can be	e copied ar	nd pasted i	nto the in	put spread	lsheet.
		1		,	0						
Contact length for point/axle lo	odc = 0.01										
Origin for loading is the middle	of the trail	nset.									
BRAKING HSLM-A1 TRAIN											
Vertical (Left power car axle 1)	TrackID	-198.7675	198 7575	17000							
		-195.7675		17000							
Vertical (Left power car axle 2)											
Vertical (Left power car axle 3)	TrackID	-184.7675		17000							
Vertical (Left power car axle 4)	TrackID		-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							
	TrackID	-91.005	-90.995	17000							
Vertical (Int. coach 5 axle 1)											
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							
				17000							
Vertical (Int. coach 8 axle 2)	TrackID	-19.005	-18.995								
Vertical (Int. coach 9 axle 1)	TrackID	-17.005	-16.995	17000							
HISLM-A1						14					
412 - 6	£ Vortio	ul (Loft nou	uar car avia	1)					(BD)	~ ~	
A13 •		al (Left pov		1)							
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A Vertical (Int. coach 9 axle 2) Vertical (Int. coach 10 axle 2) Vertical (Int. coach 10 axle 2) Vertical (Int. coach 10 axle 2) Vertical (Int. coach 11 axle 2) Vertical (Int. coach 12 axle 2) Vertical (Int. coach 14 axle 1) Vertical (Int. coach 14 axle 1) Vertical (Int. coach 14 axle 1) Vertical (Int. coach 15 axle 2) Vertical (Int. coach 16 axle 1) Vertical (Int. coach 16 axle 1) Vertical (Right end coach axle 3) Vertical (Right power car axle 3) Vertical (Right power car axle 3)	B TrackID	C -1.005 0.995 16.995 18.995 36.995 52.995 53.995 70.995 90.995 106.995 106.995 106.995 124.995 124.995 142.995 142.995 162.995 162.995 176.2225 176.2251 177.2225 191.7575	D -0.995 1.005 35.005 53.005 53.005 53.005 73.005 53.005 109.005 109.005 127.005 127.005 123.005 143.005 145.005 176.2425 178.2425 181.7675 195.7675	E 17000	F		H			К К	
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Figure 141: Select the Braking (or Acceleration) Loading to be Copied

3) Select the first **Loading Type** cell of the Train Loading Group which the HSLM-A1 trainset is to be placed in and choose **Paste Values** to only paste the data and not any formatting.

A	В	С	D	E	F	G	Н	J	
Loading	Units : Temperature : Ce	Isius , Load F	osition/Leng	th:m.Load	: kN/m				
			Ĭ						
		Amount	1						
Temperature Load	Deck								
1 · · ·	Rails								
	Ì								
	Nun	ber of Train L	oading Group	s to Analyse					
		Ĩ							
									1
			Train Lo	ading Group:	1				-
									-
	Number of Track								Nun
	Loading Locations								Loa
	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	Location Increment for each Analysis	
	Vertical (Left power car	TrackID	-198.7675	-198.7575	17000	0.01			
	Vertical (Left power car		-195.7675		17000	0.01			
	Vertical (Left power car		-184.7675		17000	0.01			
	Vertical (Left power car		-181.7675		17000	0.01		 	
	Vertical (Left end coach		-178.2425		17000	0.01		 	
Train Loads	Vertical (Left end coach		-176.2425		17000 17000	0.01		 	
	Vertical (Left end coach Vertical (Int. coach 1 ax		-163.005		17000	0.01		 	
	Vertical (Int. coach 1 ax		-161.005		17000	0.01		 	
	Vertical (Int. coach 2 ax		-145.005		17000	0.01			-
	Vertical (Int. coach 2 ax		-127 005		17000	0.01		 	
	Vertical (Int. coach 3 ax		-125.005		17000	0.01		 	•
	Vertical (Int. coach 3 ax		-109.005		17000	0.01			-
	Vertical (Int. coach 4 ax		-107.005		17000			 ·	-

Figure 142: Paste the HSLM-A1 Trainset Definition into the Loading Worksheet

4) Change the **TrackID** in the **Track Selection to be Loaded** column to represent the track that the HSLM-A1 trainset is to be passed along

5) Define the movement of the HSLM-A1 trainset loading across the structure (noting that the origin is at the centre of the loading pattern)

6) If any further trainsets are to be applied another track within the same Train Loading Group then define these below the loading that has just been defined.



Note. The principles applied here for the definition of the HSLM-A trainset loads for the Rail Track Analysis tool can be applied to other trainset configurations that include concentrated loads or can be defined in a parametric way. A single VBScript could be written which defined a range of trainsets by having different subroutines to just the writeHSLMATrain() subroutine or having a single common definition processing subroutine which tabulates the loading using internally defined arrays holding the

loading defined by multiple trainset creation subroutines. This is, however, beyond the scope of this demonstration example.

VBScript Source Code for "Define_HSLM-A_for_RTA.vbs"

The following VBScript source code performs the definition of the HSLM-A TAB delimited files containing the loading configuration in accordance with the following assumptions:

- The braking trainset load definition assumes that the HSLM-A train is moving from left to right, the accelerating trainset load definition assumes that the HSLM-A train is moving from right to left (these can be changed by simply reversing the sign of the longitudinal loading values)
- Traction loads are applied as a UDL between the front and back axles of each of the power cars only. If the maximum load of 1000kN stated in Clause 6.5.3 of BS EN 1991-2:2003 is exceeded the loading is factored to ensure only 1000kN is defined
- Braking loads are applied as a UDL over the whole length of the trainset between the first and last axles. If the maximum load of 6000kN stated in Clause 6.5.3 of BS EN 1991-2:2003 is exceeded the loading is factored to ensure only 6000kN is defined
- The point loads are defined as equivalent UDLs using a user defined contact length (default = 0.01m)
- The origin of the HSLM-A trainset is defined at the centre of the trainset configuration when specifying the locations for the trainset across the embankments and structure
- The units are kN and m in accordance with the input requirements of the Rail Track Analysis tool.

This source code is also available from the LUSAS User Area on the website.

\$ENGINE=VBSCRIPT

```
Simple VBScript to define the HSLM-A EuroCode train loads for the RTA tool
using a user-defined contact length for each point load / axle. The braking
train is travelling in the positive (to right in RTA model) direction and
the accelerating train is travelling in the negative (to the left in the RTA
model) direction. To change the directions the signs of the braking and
traction loads just need to be reversed.
This defines the loads in a TAB delimited file which can be imported into
Microsoft Excel and the data then copied and pasted into the Loading worksheet
of the RTA input Microsoft Excel spreadsheet.
NOTE: This VBScript is provided AS-IS based on the assumption that the
traction loads are applied as a UDL over the length between the first
and last axles of the powercars and the braking loads are applied as a
UDL over the entire length of the trainset axles (and factored to ensure
that the BrakingLoad <= 6000 kN condition is satisfied).
Vertical point / axle loads for the HSLM-A trainsets are applied as a
```

```
٠
       UDL over the contact length defined by the user and it is up to the user
        to ensure that this contact length is appropriate. The magnitude of the
        UDL is calculated as follows: UDL = PointForce / ContactLength
       The origin of the HSLM-A loading is the middle of the trainset.
       Units assumed are kN and m in accordance with the RTA tool.
        This VBScript is not supported by LUSAS and it is up to the user to
        decide that the assumptions above are correct.
' Dr. G.M. Paice, Project Leader, LUSAS, 14th February 2019
'==
                                                                    ______
' HSLM-A id, 1 to 10
Dim HSLMA ID
' Contact length for a point load / axle
Dim contactLength
' FileSystemObject
Dim fso
Set fso = CreateObject("Scripting.FileSystemObject")
' Output files
Dim outFile
Dim outFileName
' Dialog text
Const dialogTitle = "EuroCode HSLM-A Train Definition for RTA Tool"
Dim dialogInputText
' Current working directory (folder)
Dim CWD
CWD = qetCWD() \& "\"
' Flag for continuing
Dim contDefn
contDefn = True
                       _____
' Get the HSLM-A train ID
errTxt = "The HSLM-A train ID must be an integer between 1 and 10"
dialogInputText = Trim(InputBox("Please enter the HSLM-A train ID (1 to 10):",
dialogTitle, "1"))
If Len(dialogInputText) > 0 Then
    If isNumeric(dialogInputText) Then
       HSLMA_ID = CLng(dialogInputText)
       If HSLMA ID < 1 Or HSLMA ID > 10 Then contDefn = False
   Else
        contDefn = False
    End If
Else
    contDefn = False
End If
If Not contDefn Then
    Call MsgBox(errTxt, vbInformation + vbOKOnly, dialogTitle)
Else
    ' Get the contact length for the point/axle loads
    errTxt = "The contact length for the point/axle loads should be a positive
number and small"
    dialogInputText = Trim(InputBox("Please enter the contact length for the
point/axle loads:", dialogTitle, "0.01"))
    If Len(dialogInputText) > 0 Then
        If isNumeric(dialogInputText) Then
            contactLength = CDbl(dialogInputText)
           If Not (contactLength > 0.0) Then contDefn = False
       Else
            contDefn = False
       End If
    Else
        contDefn = False
    End If
    If Not contDefn Then
```

```
Call MsgBox(errTxt, vbInformation + vbOKOnly, dialogTitle)
    Else
        ' Get the output file (*.prn to match Microsoft Excel input)
        errTxt = "The output file should be a valid file with the *.prn extension
for import into Microsoft Excel"
        dialogInputText = Trim(InputBox("Please enter the file name for the
generated train loading (with *.prn extension):", dialogTitle, "HSLM-A" &
CStr(HSLMA ID) & ".prn"))
        If Len(dialogInputText) > 0 Then
            posPrn = InStrRev(dialogInputText, ".prn", -1, 1)
            If posPrn <> (Len(dialogInputText) - 3) Then
                contDefn = False
            Else
                outFileName = dialogInputText
            End If
        Else
            contDefn = False
        End If
        If Not contDefn Then
            Call MsgBox(errTxt, vbInformation + vbOKOnly, dialogTitle)
        Else
            ' Open the output file
            Set outFile = fso.CreateTextFile(CWD & outFileName, True)
            ' Define the HSLM-A train within the file
            Call writeHSLMATrain(outFile, HSLMA ID, contactLength)
            ' Close the output file
            Call outFile.Close()
            Set outFile = Nothing
        End If
    End If
End If
Sub writeHSLMATrain(fileObj, trainID, contLen)
'*Purpose
' Defines and writes the HSLM-A train data to the file using TAB delimited
' format.
'*Externals
' fileObj -File object
' trainID -HSLM-A train ID (1-10)
' contLen -Contact length to be used for defining the point/axle loads
'*History
' Name Date
               Comment
' GP 14Feb19 Initial coding
'*Internals
' axleCoord -Coordinates for the axles defining the HSLM-A trainset
' axleDesc -Axle description
' bogieAxle -Bogie axle spacing for each HSLM-A trainset
' brakLoadLen -Braking loaded length (overall axles for the trainset)
' brakTotLoad -Braking total load
' brakUDL -Braking load UDL after factoring for the trainset length
             -Coach lengths for each HSLM-A trainset
' coachLen
' curAxleID -Current axle ID being defined
' endCoachSpc -Spacing between the 2nd and 3rd end coach axles
' equivVertUDL-Equivalent vertical UDL for the point / axle load over the contact
length
nCoaches
             -Number of intermediate coaches for each HSLM-A trainset
 pointForce -Point / axle force for each HSLM-A trainset
 powerCarBog -Spacing between the axles of the power car bogies
' powerCarSpc -Spacing between the 2nd and 3rd power car axles
' powerEndSpc -Spacing between the last power car and the 1st end coach axle
' totNumAxles -Total number of axles for defining the HSLM-A trainset
             -Coordinate of the back of the traction loads for the power car
' tracBack
' tracFront
             -Coordinate of the front of the traction loads for the power car
' tracLenPwr -Length of the traction load for each power car
' tracTotLoad -Traction total load
' tracUDL
             -Traction load UDL after any factoring for power car length
```

```
1_____
   Dim axleCoord
   Dim axleDesc
   Dim brakLoadLen
   Dim brakUDL
   brakUDL = 20.0
   Dim curAxleID
   Dim endCoachSpc
   Dim equivVertUDL
   Const powerCarBog = 3.0
   Const powerCarSpc = 11.0
   Const powerEndSpc = 3.525
   Dim totNumAxles
   Dim tracBack
   Dim tracFront
   Const tracLenPwr = 17.0
   Dim tracTotLoad
   Dim tracUDL
   tracUDL = 33.0
 NOTE: The N number of intermediate coaches can be odd or even, therefore for
       simplicity we will initially define the point/axle loads with the origin
       at the left extent of the trainset before shifting them to be centred.
.
 In the zero-based arrays below, the index is the HSLM-A train ID minus 1
' Number of intermediate coaches, N
   Dim nCoaches(9)
   nCoaches(0) = 18
   nCoaches(1) = 17
   nCoaches(2) = 16
   nCoaches(3) = 15
   nCoaches(4) = 14
   nCoaches(5) = 13
   nCoaches(6) = 13
   nCoaches(7) = 12
   nCoaches(8) = 11
   nCoaches(9) = 11
' Coach length, D (m)
   Dim coachLen(9)
   coachLen(0) = 18.0
   coachLen(1) = 19.0
   coachLen(2) = 20.0
   coachLen(3) = 21.0
   coachLen(4) = 22.0
   coachLen(5) = 23.0
   coachLen(6) = 24.0
   coachLen(7) = 25.0
   coachLen(8) = 26.0
   coachLen(9) = 27.0
' Bogie axle spacing, d (m)
   Dim bogieAxle(9)
   bogieAxle(0) = 2.0
   bogieAxle(1) = 3.5
   bogieAxle(2) = 2.0
   bogieAxle(3) = 3.0
   bogieAxle(4) = 2.0
   bogieAxle(5) = 2.0
   bogieAxle(6) = 2.0
   bogieAxle(7) = 2.5
   bogieAxle(8) = 2.0
   bogieAxle(9) = 2.0
' Point force, P (kN)
   Dim pointForce(9)
   pointForce(0) = 170.0
   pointForce(1) = 200.0
   pointForce(2) = 180.0
```

```
pointForce(3) = 190.0
    pointForce(4) = 170.0
    pointForce(5) = 180.0
    pointForce(6) = 190.0
   pointForce(7) = 190.0
   pointForce(8) = 210.0
   pointForce(9) = 210.0
' Calculate the equivalent UDL for spreading the point/axle load over the contact
length
    equivVertUDL = pointForce(trainID - 1) / contLen
' Determine the number of axles that are required for defining the whole trainset.
' Trainset has 2 powercars + 2 end coaches + N * intermediate coaches
' Power cars have 4 axles each, end coaches have 3 axles each, intermediate coaches
have 2 axles each
    totNumAxles = 2 * (4 + 3) + 2 * nCoaches(trainID - 1)
' Dimension the storage for the axles coordinates and descriptions
    ReDim axleCoord(totNumAxles - 1)
    ReDim axleDesc(totNumAxles - 1)
' Define the left powercar
    axleCoord(0) = 0.0
    axleDesc(0) = "Left power car axle 1"
    axleCoord(1) = powerCarBog
    axleDesc(1) = "Left power car axle 2"
    axleCoord(2) = axleCoord(1) + powerCarSpc
    axleDesc(2) = "Left power car axle 3"
    axleCoord(3) = axleCoord(2) + powerCarBog
    axleDesc(3) = "Left power car axle 4"
' Define the left end coach
    axleCoord(4) = axleCoord(3) + powerEndSpc
    axleDesc(4) = "Left end coach axle 1"
    axleCoord(5) = axleCoord(4) + bogieAxle(trainID - 1)
    axleDesc(5) = "Left end coach axle 2"
    axleCoord(6) = (axleCoord(3) + axleCoord(4)) / 2.0 + coachLen(trainID - 1) -
bogieAxle(trainID - 1) / 2.0
    axleDesc(6) = "Left end coach axle 3"
    endCoachSpc = axleCoord(6) - axleCoord(5)
' Define the N intermediate coaches
    curAxleID = 7
    For icoach = 1 To nCoaches(trainID - 1)
        curAxleID = curAxleID + 1
        axleCoord(curAxleID - 1) = axleCoord(curAxleID - 2) + bogieAxle(trainID -
1)
        axleDesc(curAxleID - 1) = "Int. coach " & CStr(icoach) & " axle 1"
        curAxleID = curAxleID + 1
        axleCoord(curAxleID - 1) = axleCoord(curAxleID - 3) + coachLen(trainID - 1)
        axleDesc(curAxleID - 1) = "Int. coach " & CStr(icoach) & " axle 2"
   Next
' Define the right end coach
    curAxleID = curAxleID + 1
    axleCoord(curAxleID - 1) = axleCoord(curAxleID - 2) + bogieAxle(trainID - 1)
    axleDesc(curAxleID - 1) = "Right end coach axle 1"
    curAxleID = curAxleID + 1
    axleCoord(curAxleID - 1) = axleCoord(curAxleID - 2) + endCoachSpc
    axleDesc(curAxleID - 1) = "Right end coach axle 2"
    curAxleID = curAxleID + 1
    axleCoord(curAxleID - 1) = axleCoord(curAxleID - 2) + bogieAxle(trainID - 1)
    axleDesc(curAxleID - 1) = "Right end coach axle 3"
    curAxleID = curAxleID + 1
    axleCoord(curAxleID - 1) = axleCoord(curAxleID - 2) + powerEndSpc
    axleDesc(curAxleID - 1) = "Right power car axle 1"
    curAxleID = curAxleID + 1
    axleCoord(curAxleID - 1) = axleCoord(curAxleID - 2) + powerCarBog
    axleDesc(curAxleID - 1) = "Right power car axle 2"
    curAxleID = curAxleID + 1
    axleCoord(curAxleID - 1) = axleCoord(curAxleID - 2) + powerCarSpc
    axleDesc(curAxleID - 1) = "Right power car axle 3"
```

```
curAxleID = curAxleID + 1
   axleCoord(curAxleID - 1) = axleCoord(curAxleID - 2) + powerCarBog
    axleDesc(curAxleID - 1) = "Right power car axle 4"
' Determine the total length for the braking load and echo the length
   brakLoadLen = axleCoord(totNumAxles - 1)
    Call getTextWindow.writeLine("Braking loads will be defined over a total length
of " & CStr(brakLoadLen) & " (and factored to ensure limit is observed)")
 Determine if the braking load needs to be scaled (most likely)
   brakTotLoad = brakUDL * brakLoadLen
   If brakTotLoad > 6000.0 Then
       brakUDL = brakUDL * 6000.0 / brakTotLoad
        Call getTextWindow.writeLine("Braking load UDL has been factored as " &
CStr(brakTotLoad) & " > 6000 kN for default UDL")
   End If
    Call getTextWindow.writeLine("Braking load UDL = " & CStr(brakUDL) & " kN/m")
' Shift the axles
   Dim shiftAxles
    shiftAxles = axleCoord(totNumAxles - 1) / 2.0
   For iaxle = 0 To totNumAxles - 1
        axleCoord(iaxle) = axleCoord(iaxle) - shiftAxles
   Next
' Determine the coordinates for the power car traction loads and report the lengths
    tracFront = axleCoord(totNumAxles - 1)
    tracBack = axleCoord(totNumAxles - 4)
   Call getTextWindow.writeLine("Traction loads will be defined for each power car
length of " & CStr(tracLenPwr) & " for both leading and trailing power cars")
' Determine if the traction load for the two power cars needs to be scaled
    tracTotLoad = 2.0 * tracUDL * tracLenPwr
   If tracTotLoad > 1000.0 Then
        tracUDL = tracUDL * 1000.0 / tracTotLoad
       Call getTextWindow.writeLine("Traction load UDL has been factored as " &
CStr(tracTotLoad) & " > 1000 kN for default UDL")
    End If
   Call getTextWindow.writeLine("Traction load UDL = " & CStr(tracUDL) & " kN/m")
' Let us now write out the information to the file
   Call fileObj.writeLine("This TAB delimited file defines the HSLM-A" &
CStr(trainID) & " train definitions for a braking train travelling in the positive
(to the right) direction in the RTA model")
    Call fileObj.writeLine("and an accelerating train travelling in the negative
(to the left) direction in the RTA model.")
   Call fileObj.writeLine("")
   Call fileObj.writeLine("The vertical and braking loads for the braking train
are defined first, followed by the vertical and traction loads for the accelerating
train.")
   Call fileObj.writeLine("After importing into Microsoft Excel the appropriate
loads for the analysis being considered can be copied and pasted into the input
spreadsheet.")
   Call fileObj.writeLine("")
   Call fileObj.writeLine("Contact length for point/axle loads = " &
CStr(contLen))
    Call fileObj.writeLine("Origin for loading is the middle of the trainset.")
   Call fileObj.writeLine("")
   Call fileObj.writeLine("")
   Call fileObj.writeLine("")
   Call fileObj.writeLine("BRAKING HSLM-A" & CStr(trainID) & " TRAIN")
   For iaxle = 0 To totNumAxles - 1
        Call fileObj.writeLine("Vertical (" & axleDesc(iaxle) & ")" & Chr(9) &
"TrackID" & Chr(9) & CStr(axleCoord(iaxle) - contLen / 2.0) & Chr(9) &
CStr(axleCoord(iaxle) + contLen / 2.0) & Chr(9) & CStr(equivVertUDL))
   Next
   Call fileObj.writeLine("Braking" & Chr(9) & "TrackID" & Chr(9) &
CStr(axleCoord(0)) & Chr(9) & CStr(axleCoord(totNumAxles - 1)) & Chr(9) &
CStr(brakUDL))
   Call fileObj.writeLine("")
```

```
If brakTotLoad > 6000.0 Then Call fileObj.writeLine("Braking load UDL has been
factored as total load over the " & CStr(brakLoadLen) & " m trainset is " &
CStr(brakTotLoad) & " kN (> 6000 kN limit for default UDL)")
    Call fileObj.writeLine("Braking load UDL reduced to = " & CStr(brakUDL) & "
kN/m")
    Call fileObj.writeLine("")
    Call fileObj.writeLine("")
    Call fileObj.writeLine("")
    Call fileObj.writeLine("ACCELERATING HSLM-A" & CStr(trainID) & " TRAIN")
    For iaxle = 0 To totNumAxles - 1
       Call fileObj.writeLine("Vertical (" & axleDesc(iaxle) & ")" & Chr(9) &
"TrackID" & Chr(9) & CStr(axleCoord(iaxle) - contLen / 2.0) & Chr(9) &
CStr(axleCoord(iaxle) + contLen / 2.0) & Chr(9) & CStr(equivVertUDL))
    Next
    Call fileObj.writeLine("Traction (Left power car)" & Chr(9) & "TrackID" &
Chr(9) & CStr(-tracFront) & Chr(9) & CStr(-tracBack) & Chr(9) & CStr(tracUDL))
    Call fileObj.writeLine("Traction (Right power car)" & Chr(9) & "TrackID" &
Chr(9) & CStr(tracBack) & Chr(9) & CStr(tracFront) & Chr(9) & CStr(tracUDL))
    Call fileObj.writeLine("")
    If tracTotLoad > 1000.0 Then Call fileObj.writeLine("Traction load UDL has been
factored as total load over the two " & CStr(tracLenPwr) & " m power cars is " &
CStr(tracTotLoad) & " kN (> 1000 kN limit for default UDL)")
    Call fileObj.writeLine("Traction load UDL reduced to = " & CStr(tracUDL) & "
kN/m")
End Sub
```

References

B1 BS EN 1991-2:2003 Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges

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