# LUSAS

## Rail Track Analysis User Manual

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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/m

Resistance 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:

- **D** 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.

	A1 👻 🌗 Decks, Tra	acks and Embank	ment											¥
	A	В	C	D	E	F	G	Н	1	J	K	L	M	
1	Decks, Tracks and Embankment	Units : m												
2														
3	Number of Decks	2	]											
4	Number of Tracks	1	]											
5	Left Embankment Length	100	1											
6	Right Embankment Length	100		-										
7	Length of Decks Only / Total Length (m)	120	320											
8														
10														
11														
12														
13														
14														
15														
16														
17														
18														
19														
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14 - 4	Decks, Tracks and Embankment Stru	cture Definition	Geometric	Properties	/ Material F	Properties							▶	
	a. 97									CTT 177	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

 $\delta_p$  = displacement at top of support due to elastic deformation

 $\delta_{\phi}$  = displacement at top of support due to rotation of the foundation

 $\delta_h$  = displacement at top of support due to horizontal movement of the foundation

 $\delta_b$  = 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 <u>not</u> 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	✓ ∫ <sub>x</sub> ="Deck "&J1103													×
	A	В	С	D	E	F	G	Н	1	L	M	N	0	Р	
1	Structure	e Definition	Units : Pie	r Height : r	n : Bearing	springs on	top of each	pier : kN/n	nm, Span L	ength : m					
2				- Č	, in the second se					, i i i i i i i i i i i i i i i i i i i					
			Spring												
			Support	_			Bearing	Bearing	_	_					
			for each	Pier	Pier Geo.	Pier Mat.	Springs	Offset	Span	Geo.	Mat.				
			Abutment	Height	Assign.	Assign	on lop of	from End	Length	Assign.	Assign.				
3			/Pier				each Pier	of Deck							
1089		Span 7													-
1090		Span 8													
1091		Span 9													
1092		Number of Supports for the Deck / Length	0				0		0						
1093		Left End													
1094		Span 1													
1095		Span 2													
1096	9	Span 3													
1097	÷.	Span 4													
1098	š	Span 5													
1099	õ	Span 6													
1100		Span 7													
1101		Span 8													
1102		Span 9													
1103		Number of Supports for the Deck / Length	0				0		0						
1104															
1105															
1106															- 1
1107															- 1
1108															
1109															
1110															
1117															
1112															-
1114															
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1118															+
1119															
1120															
1121															
1122															
1123															-
14.4	► N De	cks, Tracks and Embankment Structure Definiti	on Geon	netric Prope	rties / M	aterial Prope	arties 🖉 🗍	4							•

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	✓													×
	A	В	С	D	E	F	G	Н	1	L	M	N	0	Р	-
1	Structure	e Definition													
2															
3			Spring Support for each Abutment /Pier	Pier Height	Pier Geo. Assign.	Pier Mat. Assign	Bearing Springs on Top of each Pier	Bearing Offset from End of Deck	Span Length	Geo. Assign.	Mat. Assign.				
1089		Span 7													
1090		Span 8													
1091		Span 9													
1092		Number of Supports for the Deck / Length	U						U						
1093		Left End													- 1
1094		Span 1													- 1
1095		Span 2													- 1
1096	8	Span 3													
1097	×	Span 5													
1000	ĕ	Span 5													
1100	-	Span 7													
1101		Span 8													
1102		Span 9													
1103		Number of Supports for the Deck / Length	0				0		0						
1104		Left End													
1105		Span 1													
1106		Span 2													
1107	-	Span 3													
1108	8	Span 4													
1109	Š	Span 5													
1110	ő	Span 6													
1111		Span 7													
1112		Span 8													
1113		Span 9													
1114		Number of Supports for the Deck / Length	0				0		0						
1115												<b>a</b>			
1116															_
1117															
1118															
1119															
1120															
1121															-16
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1123	E H Dec	ks Tracks and Embankment Structure Definiti	on Georg	optric Drong	etiac M	atorial Drops	arties / 🗍	4			101				
	, in Dec	any rideo dia ambanana il jordicidate Dennia	George Georg	ie die Prope	- 000 - 2 PI	doonar Prope							0		

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	X (m) Y	(m) Z (r	n) 0.5
1 Start	0 1		0.3
2 Straight	23 1	0 [ 0	Z 0.1
			-0.1
			-0.3
			AT ME TX VE EX EY
			10.5
			10.3
			10.1
	In	sert Dele	· 9.9
			9.7
Smoothing	C.c.		9.5 0 5 10 15 20
0.0	O Official line		
1	C Officente		Reverse Flip
Transverse direction —			
Perpendicular to p	ath	ĥ	Value of distance at start of path:
C Skew angle	0.0 *		• 0.0 m
C Local coordinate	2:Offset/Pier Lo	ical Coordinate	
Name Path	- Deck 1, Span 1		(pew)
	<i>,</i> ,		<b>+</b> (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	Distance interpretatio     O Scaled to fit each I     O Along reference page	n ine individually ath Path - Deck 1, S	5pan 1 💌
Section	Shape Interpolation	Distance	Edit
2-84mDepth_Section1	Start	0.0	 
			Flip
Alignment Vertical Top to top Horizontal Centre to centre	Align all sections to s       Y       Interpolation of prop	perties Enhanced	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

Table 1: Section Interpolation for Deck 1,	, Span 1	L
--	----------	---

Analysis cate Specify sl Symmetri	gory 3D nape interpolation : section	Scaled to fit each	on line individually path Path - Deck 1, Sj	pan 1 💌
	Section	Shape Interpolation	Distance	Edit
1 2-84mDep	th_Section1	Start	0.0	Insert
2 2-84mDep	th_Section2	Smoothed	5.0	Delete
3 2-84mDep 4 2-84mDep	hth_bections	Smoothed	20.0	
5 2-84mDep	h_Section1	Smoothed	25.0	Flip
Horizontal	Right to right	Interpolation of pro	pperties Enhanced	•
1	2	3	4	100% 5
i Sec	ż	3 1 1 2-2 Section 3-3 Sect	i tion 4-4 Section	ś 15-5
Na	me 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 ( $\rho$ ) 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 Pr	operties Between Rail/Sl	ab						
A	В	С	D	E	F	G H	1	J
1 Interaction Joint Properties Between Rail/Slab	Units : Bilinear springs cl			ricity between r				
2	-							
3		Eccentricit	Retween Rail/S	lab				
4		(+)	ve Sense)					
5			/					
6	•	•	/ N	odal Line Of Tra	ick/Rail			
7			f					
8		-						
9		-						
	+	+						
10								
12			7					
14			//	leutral Axis Of S	ection			
15	-	/	/					
16		/	/					
17		$\setminus$ /	/					
18			/					
19			/ Location	Of Support Cor	ditions			
20			4					
21		1						
22		Depth Of Section	in					
23								
24					1			
25 Eccentricity between Rail/Slab	0							
26 Parametric Distance of Interaction Joint from Rail	0.5		-					
27 Item	Classic Casing Cliffords	Longitudinal	Iransverse	Vertical				
20 19 Unloaded Bilinear Springe Characteristic	Viold Earon	80	inimite	ininite				
an annoacea onnear oprings citatacteristic	Hardaning Stiffnace	40	infinite	infinite				
31	Flastic 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, Initi	ial gap : mm						
37								
38		Tra	:k 1	Tra	ick 2			
39		Position	Initial Gap	Position	Initial Gap			
40	1	300	5					
41	2	475	5	475	5			
42	3			625	5			
H ← → H / Geometric Properties / Material Properties In	teraction and Expansion	Joint / Loading	/2/ 1	(		11		•

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.



Figure 35: Adding Extra Train Loading Groups (Copy)





# **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 loa	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

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 me	odel	
Original model filename	Brows	se
Rail load model filename		
Rail load Microsoft Excel spreadsheet or batch text file	Brows	se
☑ Wait for solution		
	OK Cancel Hel	P

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	×
Filename	
Working folder	
<ul> <li>Current</li> <li>C User defined</li> </ul>	
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	В	C	D	E	F	G	н		1	K	L	N1	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 Stre (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	-1.978
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	-2.027
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	+2.027
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	-2.127
05	48	43		3	-297	0	0	-2.92E-24	9.113E-218	1.81E-215	-2.92E-24	-3.262E-15	1.76E-208	5.203E-209	-2.127
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	-2.279
07	51	46		4	-296	0	0	-4.005E-24	-3.55E-217	-7.05E-215	-4.005E-24	-3.496E-15	-6.85E-208	-2.03E-208	-2.279
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	-2.488
09	56	49		5	-295	0	(	-5.19E-24	1.381E-216	2.746E-214	-5.19E-24	-3.816E-15	2.669E-207	7.892E-208	-2.488
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	-2.759
11	59	52		6	-294	0	6	-6.504E-24	-5.38E-216	-1.07E-213	-6.504E-24	-4.232E-15	-1.04E-206	-3.07E-207	-2.759
12	63	52		6	-294	0	(	-6.504E-24	-5.38E-216	-1.07E-213	+6.504E-24	-4.752E-15	4.048E-206	1.197E-206	-3.098
13	63	55		7	-293	0	0	-7.979E-24	2.094E-215	4.165E-213	-7.979E-24	-4.752E-15	4.848E-286	1.197E-206	-3.096
14	67	55		7	-293	0	(	-7.979E-24	2.094E-215	4.165E-213	-7.979E-24	-5.39E-15	-1.58E-205	-4.66E-206	-3.514
15	67	58		8	-292	0	0	-9.653E-24	-8.16E-215	-1.62E-212	-9.653E-24	-5.39E-15	-1.58E-205	-4.66E-206	-3.514
16	71	58		8	-292	0	(	·9.653E-24	-8.16E-215	-1.62E-212	·9.653E-24	-6.162E-15	6.14E-205	1.016E-205	-4.019
17	71	67		9	-291	0		-1.157E-23	3.177E-214	6.318E-212	-1.157E-23	-6.162E-15	6.14E-205	1.816E-205	-4.018
18	76	62		9	-291	0		-1.157E-23	3.177E-214	6.319E-212	-1.157E-23	-7.0BRE-15	-2.39E-204	-7.07E-205	-4.621
19	76	65		10	-290	0		-1.377E-23	-1.24E-213	-2.46E-211	-1.377E-23	-7.088E-15	-2.39E-204	-7.07E-205	-4.621
20	79	65		10	-290	0		-1.377E-23	-1.24E-213	-2.46E-211	-1.377E-23	-8.189E-15	9.313E-204	2.754E-204	-5.335
21	79	66		11	-789	0		-1 631E-23	4.8195-213	9 583E-211	-1 631E-23	-8 189E-15	9 3135-204	2 754F.204	.5 339
22	83	66		11	-289	0		-1.631E-23	4.8195-213	9.5835-211	-1.631E-23	-9.494E-15	-3.63E-203	-1.07E-203	-6.185
23	83	71		12	-288	0		-1 926E-23	-1.88E-212	-3 73E-210	-1 926E-23	-9 494E-15	-3 63E-203	-1 07E-203	-6.185
2.4	07	71		12	.200			-1 9365-23	-1.005-212	-2 725-210	-1.9265-23	-1.1025-14	1 41 95-202	4 1775-202	.7 195
24	07	71		12	-200	0		-2.9206-29	7 2095-212	1.4546.200	-2.3200-23	-1.1036-14	1.4196-202	4.1776-203	-7100
26	91	74		13	-207	0		-2.2006-23	7 2095 212	1.4546.200	-2.2006-23	1 2055.14	5 5E-202	1 625-202	.0 270
	91	72		13	-207	0		-2.200E-23	2.055.212	L.404E-207	-2.200E-23	-1.203E-14	-3.3E-202	-1.63E-202	-0.370
	51	77		14	-206	0		2.6676-23	2.055.211	13.66E1203	12.667E-23	1,2005-14	-5.5E-202	1.6321202	10.370
20	23	70		19	-200	0		-2.667E-23	-2.030-211	-3.00E-207	-2.607E-23	-1.4705-14	2.1432-201	6.330E-202	-3,767
22	33	73		15	-205	0		3.1326-23	1.1092-210	2.2056-208	-3.132E-23	1.7405.1.4	2.1432-201	5.336E-202	13.767
50	99	79		15	-285	0		-3.152E-23	1.109E-210	2.205E-208	-3.132E-23	-1.7498-14	-8.34E-201	-Z.47E-201	-1.14
51	99	83		16	-284	0		-3.6/5E-23	-4.32E-210	-8.59E-208	-3.675E-23	-1.749E-14	-8.34E-201	-2.47E-201	-1.14
52	104	83		16	-284	0		-3.6/3E-23	-4.32E-210	-8.59E-208	-3.6/3E-23	-2.0432-14	3.25E-200	9.616-201	-1.352
53	104	84		1/	-283	0		-4.309E-23	1.682E-209	3.344E-207	-4.309E-23	-2.043E-14	3.25E-200	9.61E-201	-1.332
84	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	-1.557
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	-1.557
86	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	-1.82
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	-1.82
38	116	91		19	-281	0	(	-5.917E-23	2.551E-208	5.072E-206	+5.917E-23	-3.265E-14	-1.92E-198	-5.68E-199	+2.129
39	116	94		20	-280	0	(	-6.931E-23	-9.93E-208	-1.98E-205	+6.931E-23	-3.265E-14	-1.92E-198	-5.68E-199	-2.129
40	119	94		20	-280	0	6	+6.931E-23	-9.93E-208	-1.98E-205	+6.931E-23	-3.819E-14	7.477E-198	2.211E-198	-2.49
41	119	96		21	-279	0	(	-8.116E-23	3.869E-207	7.694E-205	-8.116E-23	-3.819E-14	7.477E-198	2.211E-198	-2.49
42	123	96		21	-279	0	6	-8.116E-23	3.869E-207	7.694E-205	+8.116E-23	-4.469E-14	-2.91E-197	-8.61E-198	-2.913
82	123	99		22	-278	0	(	-9.504E-23	-1.51E-206	-3E-204	-9.504E-23	-4.469E-14	-2.91E-197	-8.61E-198	-2.913

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	UH	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	0	1.9998E-12	-9.82E-175	-2.34E-175	1.3037E
01	39	38		1	-299	0		0 6.2083E-22	-7.43E-184	-9.02E-182	6.2083E-22	1.9998E-12	-9.82E-175	-2.34E-175	1.3037E
92	44	38		1	-299	0		0 6.2083E-22	-7.43E-184	-9.02E-182	6.2083E-22	2.0495E-12	3.641E-174	1.095E-174	1.33618
03	44	39		2	-298	0		0 1.2571E-21	1.971E-183	3.752E-181	1.2571E-21	2.0495E-12	3.641E-174	1.095E-174	1.33618
04	48	39		2	-298	0		0 1.2571E-21	1.971E-183	3.752E-181	1.2571E-21	2.15E-12	-1.43E-173	-4.22E-174	1.40178
05	48	43		3	-297	0		0 1.9246E-21	-7.38E-183	-1.47E-180	1.9246E-21	2.15E-12	-1.43E-173	-4.22E-174	1.40176
06	51	43		3	-297	0		0 1.9245E-21	-7.38E-183	-1.47E-180	1.9246E-21	2.304E-12	5.553E-173	1.642E-173	1.50218
87	51	46		4	-296	0		0 2.6398E-21	2.873E-182	5.713E-180	2.6398E-21	2.304E-12	5.553E-173	1.642E-173	1.50218
08	56	46		4	-296	0		0 2.6398E-21	2.873E-182	5.713E-180	2.6398E-21	2.5152E-12	-2.16E-172	-6.39E-173	1.63978
09	56	49		5	-295	0		0 3.4206E-21	-1.12E-181	-2.23E-179	3.4206E-21	2.5152E-12	-2.16E-172	-6.39E-173	1.63978
10	59	49		5	-295	0		0 3.4206E-21	-1.12E-181	-2.23E-179	3.4206E-21	2.7888E-12	8.422E-172	2.49E-172	1.81818
11	59	52		6	-294	0		0 4.2864E-21	4.357E-181	8.666E-179	4.2864E-21	2.7888E-12	8.422E-172	2.49E-172	1.8181
12	63	52		6	-294	0		0 4.2864E-21	4.357E-181	8.666E-179	4.2864E-21	3.1318E-12	-3.28E-171	-9.7E-172	2.0417
13	63	55		7	-293	0		0 5.2587E-21	-1.7E-180	-3.37E-178	5.2587E-21	3.1318E-12	-3.28E-171	-9.7E-172	2.0417
14	67	55		7	-293	0		0 5.2587E-21	-1.7E-180	-3.37E-178	5.2587E-21	3.5524E-12	1.277E-170	3.777E-171	2.316
15	67	58		8	-292	0		0 6.3615E-21	6.609E-180	1.314E-177	6.3615E-21	3.5524E-12	1.277E-170	3.777E-171	2.316
16	71	58		8	-292	0		0 6.3615E-21	6.609E-180	1.314E-177	6.3615E-21	4.0614E-12	-4.98E-170	-1.47E-170	2.64788
17	71	62		9	-291	0		0 7.6224E-21	-2.57E-179	-5.12E-177	7.6224E-21	4.0614E-12	-4.98E-170	-1.47E-170	2.6478
18	76	62		9	-291	0	-	0 7.6224E-21	-2.57E-179	-5.12E-177	7.6224E-21	4.6712E-12	1.938E-169	5.729E-170	3.04538
19	76	65		10	-290	0		0 9.0725E-21	1.002E-178	1.994E-176	9.0725E-21	4.6712E-12	1.938E-169	5.729E-170	3.0453
20	79	65		10	-290	0		0 9.0725E-21	1.002E-178	1.994E-176	9.0725E-21	5.397E-12	-7.55E-169	-2.23E-169	3.5185E
	79	66		11	-289	0		0 1.0748E-20	-3.9E-178	-7.76E-176	1.0748E-20	5.397E-12	-7.55E-169	-2.23E-169	3.51858
	83	66		11	-289	0		0 1.0748E-20	-3.9E-178	-7.76E-176	1.0748E-20	6.2568E-12	2.939E-168	8.69E-169	4.0798
	83	71		12	-288	0		0 1.269E-20	1.521E-177	3.024E-175	1.269E-20	6.2568E-12	2.939E-168	8.69E-169	4.0798
24	87	71		12	-288	0		0 1.269E-20	1.521E-177	3.024E-175	1.269E-20	7.272E-12	-1.14E-167	-3.38E-168	4,7409
25	87	72		13	-287	0		0 1.4948E-20	-5.92E-177	-1.18E-174	1.4948E-20	7.272E-12	-1.14E-167	-3.38E-168	4,74098
26	91	72		13	-287	0		0 1.4948E-20	-5.92E-177	-1.18E-174	1.4948E-20	8.4679E-12	4.458E-167	1.318E-167	5,5205
27	91	77		14	-286	0		0 1.7577E-20	2.306E-176	4.587E-174	1.7577E-20	8.4679E-12	4.458E-167	1.318E-167	5,52058
28	95	77		14	-286	0		0 1.7577E-20	2.306E-176	4.587E-174	1.7577E-20	9.874E-12	-1.74E-166	-5.13E-167	6,4372
29	95	79		15	-285	0		0 2.0642E-20	-8.98E-176	-1.79E-173	2.0642E-20	9.874E-12	-1.74E-166	-5.13E-167	6.43728
30	99	79		15	-285	0		0 2.0642E-20	-8.98E-176	-1.79E-173	2.0642F+20	1.1525E-11	6.751E-166	1.9995.166	7.5138
31	99	83		16	-284	0		0 2.4228-20	3.498E-175	6.957E-173	2.422E-20	1.1525E-11	6.761E-166	1.999E-166	7.5138F
32	104	83		16	-784	0		0 2.4225-20	3.498E-175	6.957E-173	2.422F+20	1.34635.11	-2.63E-165	.7.79E.166	8.777
33	104	84		17	-283	0		0 2.84F-20	-1.36E-174	-2.71E-172	2.84E-20	1.3463E-11	-2.63E-165	-7.79E-166	8.7778
24	107	84		17	-203	0		0 2.84E-20	-1.36E-174	-2.71E-172	2.84F-20	1.57355.11	1.0265-164	3.0335-165	1.02586
35	107	87		18	-203	0		0 3.3284E-20	5.306E-174	1.055E-171	3.3284E-20	1.5735E-11	1.026E-164	3.033E-165	1.02586
26	112	87		18	-202	0		0 3.3284E-20	5.306E-174	1.055E-171	3.3284E-20	1.83985-11	-3.99E-164	-1.18F-164	1.1994
37	112	91		19	-202	0		0 3.8996E-20	-2.07E-173	-4.11E-171	3.8996E-20	1.83985-11	-3.99E-164	-1.18F-164	1.1994
28	116	91		19	-201	0		3.89965-20	-2.07E-173	-4.11E-171	3.89965-20	2.15175-11	1.556E-163	4.6F-164	1.40285
20	116	94		20	-201	0		0 4 5676E-20	0.040E-173	1.6016-170	4 5676E-20	2.15176-11	1.5566-163	4.65.164	1.40205
v7 A0	110	94		20	-200	0		4.56766-20	0.040E-170	1 6016-170	4.56766-20	2 51715-11	-6 06E-163	.1 795.163	1 6416
~9 41	119	94		20	-279	0		5 3,095-20	-3 13E-172	-6 235-170	5.3495-20	2.51716-11	-6.06E-163	-1.795-163	1 6418
~1 12	100	20		21	-275	0		0 5 2,005 20	-9.196-172	-6.235-170	5 2/06.00	2 94515.11	2 359E-163	6.9775.149	1.0410
**	123	20		21	-279	0		0.543E-20	- J. 13E-172	3.430F.100	6 36335 38	2.04515.11	2.35352-162	C 077F 1/23	1.020
-2	123	27 1 1 (Teach	2 / Darks / Fnushna - Track t / Fnush	re-Track 2	Freelone - Deck	C Dailbed	Charle / D	0-2053E-20	a-ac10-171	s. 459E-163	0.20306-20	**********	2.0002-162	0.2772-103	

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)
- **U** 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.

8	C	D	E	F	G	н	1	J	K	L	
1	Check of Longitudinal Relative Displacement	t of Railbed (Relativ	e Displacement	between Rails	and Deck)						
•	circle of congregation in the art completement	contained present	e onparecimente	Decirconnuns	and been						
Job Title:	UIC 774-3 Model: UIC774Hwashi101Param										
alisis Filename:	UIC776Hwashil0Param*Position1-> UIC776Hwashil0Para	n*Position 101									
Model Directory	CAProjects's J12504's Track Structure Interaction										
Analysis Date:	26V03/2019> 28/03/2019										
Model Units:	N/m.kg.s,C										
			Track 1			Track 2					_
			Distance from	Distance from		Distance from	Distance from	Peak Relative		Distance from	
A	B		Left End of the	Left End of the		Left End of the	Left End of the	Longitudinal	Track Number	Left End of	Deser
Analysis ID	Plesuits Filename	Loading 1 gpo	Model to the	Model to the	Loading Type	Model to the	Model to the	Displacement	with Peak	Structure for	peak
1			Starting	Finishing		Starting	Finishing	between Hail	Displacement	Peak	
L .	UCTION AND INFORMATION AND A	Tomas and Date	Position of the	Position of the	Tomas and the Oak	Position of the	Position of the	and Slab [m]		Displacement	Fac Abre
	UC778Hastelling wan Position Imp	Explanation Control Control		100	docely ating	310	600	0.0073350097		0.00	DL AL
	Incrating and a second second second	Dealing	6.76	201.00	Assolution	100.16	003.36	0.007378306		200	FR.( Ab.)
	UCT/INVISION- a an Position 2 mgs	Craning	0.44	305.20	novemaning	200.20	00320	0.007373039		-	10000
	UC 774House and Provide A mar	Ending	10.75	112.5	Accesserating	100.3	006.5	0.007266422		0.00	EN AL
	Contractioner and Provide English	Crating	10.75	111.70	Accelerating	100.70	000.00	0.007360636		000	C
2	Contraction of the second states of the second stat	Dealing	21	320	Annalisation	303	613	0.007358531		327	100 000
	UCTIVITY ASTRONOM A AN I COSTOLING THE	En antig	3125	1,125	cover aling	16.0	68.20	0.007306905		240	100.004
1 1	UP 7164 vitability was Position 9 mar	Erwite Datis	40.75	3375	Accelerating	303.5	610.5	0.007344906		241	DL AN
1 8	Contraction and Position and State	Draking	43.75		Accelerating	322.76	622.75	0.00734798		327	THE ADD
	UCTORNASIAN Para Position 3 mgs	cranity)	04	200	nuvern allig	325	605	0.007343822		347	100 004
10	UC TIEL AND DE ANT PORTO EMPI	Ending	56.25	395.25	Hooeverating	229.25	629.25	0.00735003		245	ELL AT
	ACTIVITY AND TO ANY ANY POSITION TO ANY	braing	62.5	362.5	move we aring	332.5	632.5	0.007357474		307	CT LAN
2	Dic menuastania a ani Positich 12 mgs	Cranity Endorse	68.71	38.75	Access allig	38.0	6,0./5	0.007361/58		367	THU AC
<u>v</u>	UIC//HHVASHAILIP/a/am-Position LLmgs	eraing		3/5	Hooeseraing	319	6.0	0.007364032		10	1000
	UCTOR AND	Cratics .	0125	30125	novem ality	342.25	04225	0.007363365		247	ABU
5	OIC // Verwashallolm and mimosistion is migs	Draung	07.5	307.5	Access asing	240.5	040.0	0.007375625		025	FIN ADD
8	UIC//4HvashilliParam-Position temps	eraing	84.75	30.75	Accelerating	348.75	648./0	0.00738173	-	80	HH ADU
17	UIC774HvashilliPaam*Position17.mgs	Draking	100	400	Accelerating	352	652	0.007388264		202	FPI Abu
10	UIC774Huashill@wam"Position II.mgs	Draking	106.25	405.25	Accelerating	386.25	655.25	0.007409635	-	325	FPH Abu
19	UIC774HvashifttParam*Position18.mgs	Enaung	112.1	412.5	Accelerating	398.5	658.5	0.007413397	2	325	HH ADU
20	UIC774HwashilliParam*Position 20 mgs	Eraking	19.75	419.75	Accelerating	36175	661.75	0.007427392		225	FH Abu
21	UC774HvashBBP aram Position 21.mgs	Draking	121	425	Accelerating	365	665	0.007440419		1/1	Plat 7
22	UIC774HvashfillParam*Position22.mgs	Exalung	131.25	43125	Accelerating	388.25	66125	0.007535/93		1/5	Pher 7
23	UIC/74HvashillParam*Position21/hgs	Eraing	197.5	437.5	Accelerating	3/15	8/10	0.007647694		1/5	Pher /
24	UIC774Hvashill@Paam*Position.24/mgs	Eraking	143.71	443.75	Accelerating	374.75	674.75	0.007704441		117	Plet 7
	OIC // WHATHERD P & MT POSITION 25 Mys	braing	156	450	Hooeweating	3/6	6/0	0.007576226		115	Plat /
28	UIC//RHvashilltParam*Position.26/mgs	Exaung	156.25	498.25	Accelerating	38125	68125	0.008227912		10	Phan 2
27	UIC774Hwashill0IP aram "Position 27 mgs	Braking	902.5	492.5	Accelerating	204.5	694.5	0.00051110		170	Piet 7
20	UIC 774PHASHBUP & ATT POSITION 28 Mgs	Er word	86.71	468.75	Accession	307.75	667.75	0.0000194177		1/1	Pher 7
29	UIC774HvashfillP'aram Position 25 mgs	Exalung	1/5	4/5	Accelerating	391	691	0.00953004		10	Pher 7
30	UIC/74Hvashittleraram-Position 30/mgs	Eraing	191.21	49125	Accessrating	294.25	694.25	0.009000075		1/5	Pher /
31	UIC774HwashillitParam*Position 3Lmgs	Enaking	107.5	497.5	Accelerating	397.5	697.5	0.008877371		110	Pher 7
22	UIC774HvashillIParam*Position 32.mgs	Einaking	100.75	493.75	Rocelecating	400.75	700.75	0.006/79173		1/2	Pier 7
31	UIC774HvashfiltParam*Position 33/mgs	Exaung	200	500	Accelerating	414	/04	0.009590034		10	Pher 7
34	UIC774Hwashill0IP aram "Position 34.mgs	Draking	206.25	506.25	Accelerating	407.25	707.25	0.000468225		170	Piet 7
30	UIC 774HAASHAILIP A ATT POSITION 35 Mgs	eraing	2121	912.0	Rooeerating	410.5	780.5	0.000343203		1/7	Pher 7
36	UIC 774Hv ashfill P'ar am "Position 36 mgs	Enaking	218.75	518.75	Accelerating	413.75	70./5	0.038317439		250	Pher 10
37	DIC //RPMashanim-aram-Position 27 mgs	enaning	225	625	nooewrating	40	717	0.009562548		250	P141 10
38	UIC / HTM as HOP & ATT POSITION 31/165	Examp	23125	631.26	moneterating	420.25	1 720.25	0.009927527		250	1756110
29	UL //www.stellip.a.am. Position 23 mgs	uraung	237.5	5375	Hooeweating	4215	7235	0.005/29661		250	Pher 10
60	Mul remeased DP a am Position 40 mgs	to wing	243.75	943.75	mode We along	426.75	r28.75	0.009452968		290	1734110
	OUC / / TYTWashinton aram 'Position 41.mgs	trating	250	550	Accentiating	430	730	0.009782891		250	Par II
42	UIC//HHVashimParamPosition42.mgs	Eraung	256.25	1 556.25	mooeterating	433.25	1 733.25	0.009625799		250	Pher 10
43	UL (APPASTENCE & an Position 43 mgs	uraung	262.5	562.5	HOOPHEATING	436.5	736.5	0.003455656		250	Priet 10
	OC //Physical and Position 44 mays	the working	260.75	661.75	nooewrating	439.75	739.75	0.003255004		200	P141 10
60	or remainment an Position 45/765	Cravity)	275	6/6	noormablig	443	1 743	0.009125299		200	mel 10
46	UIL / / HPVasterum aram Prosition 46 mgs	eraung	2912	59125	Hooelecating	446.25	746,25	0.009007622		250	Pher 10
1 17	Multi remaination and Position 47 mgs	the white g	207.5	597.5	more # We along	449.5	749.5	0.000912503		325	TPT Abs
43	OIC // HPV as renormal am Prosition 45 /rigs	Dravity)	293.75	693.76	nocentality	462.75	762.75	0.009122915		325	THI ADG
49	UIC//HHVashimParamPosition49.mgs	Eraung	300	600	mooeterating	456	756	0.009148895		325	HPH ADU
50	UL remaining an Position Strags	Draking	206.25	001.25	mootherating	459.25	1 759.25	0.003043033		225	191 Abu
51	OC // Posterior a an PostionStrigs	Draning	312.5	612.5	Accenting	462.5	742.5	0.000000000		325	FFT Abu
6	UIC778HvasMITEParam*Position52.mps	Enauty	318.75	618.75	Accelerating	465.75	765.75	0.009139484		325	HH Abu
50	UIC774HvashIIIIParam*Position53.mgs	Eraking	325	625	Accelerating	469	763	0.009/32716		325	FH Abu
54	UIC // Ph/Asheliter ar am Position 54 mgs	Draking	301.21	63125	Accelerating	472.25	772.25	0.003200688		325	PP1 Abs
55	UIC774HvashilttParam*Position55.mgs	Ex along	337.5	637.5	Accelerating	475.5	775.5	0.009229563		325	PPH Abu
56	UIC774Hwashill0IParam*Position/56.mgs	Braking	343.71	643.75	Accelerating	478.75	778.75	0.003224294	2	325	FH Abu
57	UIC774HvashilliParam*Position57mgs	Draking	350	650	Accelerating	412	782	0.003230825		325	FHI Abs
58	UIC774HvashillIP a am*Position58 mgs	Braking	356.25	654.25	Accelerating	485.25	705.25	0.009236702		325	PH Abu
59	UIC774Hwashilt0Param=Position/99.mgs	Braking	362.5	662.5	Accelerating	488.5	788.5	0.009237485	2	325	FH Abu
60	UIC774Hvashil0IParam*Position90.mgs	Braking	368.71	668.75	Accelerating	49175	791.75	0.00323643	1	225	FH Abu
61	UIC774HvashillIP a an "Position 61 mgs	Draking	371	675	Accelerating	415	795	0.009233461	1	325	FHI Abut
62	UIC774HvashittitParam*Position/62.mgs	Exaking	381.25	681.25	Accelerating	498.25	798.25	0.003228364	2	325	FH Abu
60	UIC774Hvashilt0Param*Position63.mgs	Braking	387.5	697.5	Accelerating	501.5	8015	0.009221938	8	325	FH Abu
	THE THE ALCOHOLD OF MILLION EX MAN	Electricat	100.18	E 693 W	Assalutation	E	E 004 78	0.0000000000000000000000000000000000000		1	THE AREA

Figure 54: Railbed Check Worksheet for Multiple Results Files

8	C	0	E	F	G	H	1	J	K
	<b>Check of Longitudinal Relative Displace</b>	nent between Ends (	of Decks (Axial	)					
-									
Job Title:	UIC 774-3 Model: UIC 774Hv ashi101Param								
Analysis Filename:	UIC774Hvashi101Param*Position 1> UIC774Hvashi101P	aram Position 101							
Model Directory:	C:IProjects/J72504/TrackStructureInteraction								
Analysis Date:	28/03/2019> 28/03/2019								
Model Units:	N.m.kg.s.C								
			* * *			× 1.0			
			Track 1	0		Track Z	0	0.101	0
			Distance from	Distance from		Distance from	Distance from	Peak Relative	Pier Nullio
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
			Pladel to the	Model to the		Prodel to the	Pladel to the	Ends of Dasks Desition	Dashawi
-	187774Marcada (204Decore/Decolders 1 areas	Tamenan en Ont-	Janung	ransang	Terran and the Oak	January	ransming	0.034506054	Decks Th
-	1877744 and 2010 Planam Postion 1 most	Bahing		303	Assolution Only	300	600	0.04000004	Dive 10
2	187774Hu and 2010 and 7 Cardina 2 mars	Relies	6.25	206.25	Assolution	300 26	602.25	-0.014901299	Dire 10
	LIC 774He add 10 Parat Postion 3 mer	Braking	12.5	312.5	Acceleration	306.5	606.5	-0.01490964	Plor 10
1 1	18"774MarshelfWIDaram"Dacking Amor	Baking	10.75	210.75	Accelerating	209.75	609.75	-0.044912903	Dist 10
	18"77/Marsh 2010 aram Position 5 more	Reduce	25	225	Accelerating	212	613	-0.04926743	Direct 10
-	LIC774Headed 101Daram Doction Survey	Braking	20 10	329 32	Acceleration	340.00		0.014020143	Pier 10
9	LIC774Huadul TOParan Position 7 mus	Baking	31.65	397 6	Acceleration	395.6		0.014330104	Pix 11
1 4	18774HeadelTDParam Position 8 mes	Braking	49.76	349.76	Acceleration	3(20.76	620.76	-0.014463649	Pier 11
	LIC 774Ma add/001Dager/Depitien 9 mars	Reduce	43.10	343.75	Annalisating	322.75	622.75	-0.0M364623	Dia 10
10	LIC 27/Mile adv/10/Decam/Decition 10 more	Balana	50 25	350 350	Accelerating	229.25	620 25	-0.05490E22	Dist 10
11	18°774Hz adv/WDaram/Dartino 11 mor	Balan	30.60	300.65	Accelerating	363.63	632.6	-0.0 H30533	Divi 10
12	187774Ma adul/01Param/Pacition 12 mot	Relies	62.0	362.5	(Leaster sting)	235.0	632.0	-0.015005503	Pin 10
12	LIC 774Ma add/01D same Dation 12 mar	Relies	260.10	366.75	Accelerating	335.75	630.75	-0.015024525	Disc 10
10	18°774Hu adulf01Daram/Doction 14 mort	Balan	81.25	301.25	Acceleration	342.25	642.25	-0.0506253	Divi 10
15	18°77/Hu adul YiParan Daviso K mat	Balan	87.5	301.25	Accelerating	346.6	645.50	-0.015067153	Rive 10
10	187774Ma add/01D area Desition 16 mar	Darking	93.75	292.75	Accelerating	340.0	640.5	-0.015031515	Pier 10
10	LIC 774Hz add 101Daram/Doction 17 mort	Baking	33.15	333.15	Accelerating	340.73	040.75	-0.0515076	Dist 10
10	Lac 1 Hit Hanna M Pranam Prosition 17, Hos	Crailing .	100	400	Accelerating	352	052	-0.05940053	0
10	City I remease to manage Position 10, figs	Charling	100.20	406.25	Accelerating	300.25	600.25	-0.015106563	P (01 10
19	List 1 White aprel to Pranam Prosition 13, Hys	Charles (	112.5	412.5	Accelerating	358.5	658.5	-0.05228264	Dist 10
20	Lac 27 Maria Arra Minaram Position 20, mys	Rederig	118.75	418.15	Accelerating	391.75	661.75	-0.015269024	07
21	Lac 11 mm done to manamin roshion 21 mgs	Charling .	120	4/2	Accelerating	300	005	-0.015401333	07
22	UK, I INTRASILI U Param Postion 22 mys	Draking	131.25	\$31.25	Accelerating	368.25	068.25	-0.01557328	CNI C
23	LICT 7444 with Min and Press Position 23 mps	Rederig	137.5	437.5	Accelerating	3/15	671.5	-0.05758342	07
24	Lac 11 mm done Minimum Publishing 26 mm	Realized	93.15	443.75	Accelerating	3/4/0	0/4/2	-0.06365333	07
25	UK, FIRM Mashill U Palam Postion 20.mys	Drawing	150	450	Accelerating	378	678	-0.016754157	Part C
26	Call Form and UP aram Position 20. mys	Drawing	16.25	456.25	Accelerating	381.25	ed125	-0.063333193	Call C
27	UL / PHTH ARM UP ALM Position 27 mys	Draking	162.5	462.5	Accelerating	384.5	684.5	-0.0%539634	PMI 7
28	UIL ( PHTH ASHI U IParam Position 28 mys	Oraxing	188.75	468.75	HCOelerating	367.75	687.75	-0.016755675	Pierr
29	UL rinneased Ultraram Position 20 mys	Draking	175	475	Mccelerating	39	691	-0.016910744	PHIC
30	Cit. / Petro aind Dimaram Position 30 mys	Dracing	101.25	401.25	Accelerating	394.25	694.25	-0.0168306	PWI /
31	UL CHINASH UP alam Position 31 mys	Draking	187.5	487.5	HCCelerating	397.5	697.5	-0.016801896	Pier C
32	ULL CRITH ASHI U Haram Position 32 mys	Oraxing	153.75	493.75	Mcoelerating	400.75	700.75	-0.016/17/43	PHER
33	City of Permission Difference Position 33 mys	Drawing	200	500	Accelerating	404	704	-0.016534624	Piet r
34	Us. I Petre aine Dimaram Position 34 mys	Draking	206.25	506.25	Accelerating	407.25	107.25	-0.01671465	Priet to
35	UR, I HATH AshiTUTP aram Position 35 mys	Braking	212.5	512.5	Hooelerating	410.5	710.5	-0.0%905129	10.000
36	UIC / MPH ashi UTP aram Position 36 mps	Draking	218.75	518.75	Accelerating	413.75	713.75	-0.017067318	PW170
37	UIC 114He ashill UIP aram Position 37.mys	Braking	225	525	Accelerating	417	717	-0.017255659	Pier 10
38	UIL / /4He ashi/UIP/aram Position 38 mys	Braking	231.25	531.25	Accelerating	420.25	720.25	-0.017420871	Plet TU
39	UIL / MPH ashi UIP aram Position 39 mus	Braking	237.5	537.5	Accelerating	423.5	723.5	-0.017612033	Pletau
40	UIC 114Pticashil 101Param Position 40, mys	Draking	243.75	543.75	Accelerating	426.75	726.75	-0.01781256	PWH TO
41	UIL / / 4Hv ashil 10 IP ar an "Position 41 mys	Braking	250	550	Accelerating	430	730	-0.017947893	Pier 10
42	UIL / /HHwashil UIParam Position 42 mys	Braking	256.25	556.25	Accelerating	433.25	733.25	-0.01783201	Pertu
43	UIC774Hwashil101Param*Position 43.mys	Braking	262.5	562.5	Accelerating	436.5	736.5	-0.017756247	Pier 10
44	UIL 114Pte ashel UIP aram Position 44.mys	Braking	268.75	568.75	Accelerating	439.75	739.75	-0.017632055	Pier to
45	UIL / /HH ashi UIParam Position 45 mys	Braking	275	575	Accelerating	443	743	-0.017504237	Plet 10
46	UIC774Hwashil101Param'Position 46 mys	Braking	281.25	581.25	Accelerating	446.25	746.25	-0.017341322	Pier 10
47	UIC774Hwashi101Param*Position 47.mys	Braking	287.5	587.5	Accelerating	443.5	749.5	-0.017206085	Pier 10
48	UIC774He ashil 101Param Position 48 mys	Braking	293.75	593.75	Accelerating	452.75	752.75	-0.017076525	Pier 10
49	UIC774Hwashil101Param/Position 43 mys	Braking	300	600	Accelerating	456	756	-0.015970881	Pier 10
50	UIC774Hwashil101Param*Position 50.mys	Braking	306.25	606.25	Accelerating	458.25	759.25	-0.016892426	Pier 10
51	UIC 774Hw ashi/101Param Position 51 mys	Braking	312.5	612.5	Accelerating	452.5	762.5	-0.016829107	Pier 10
52	UIC774He ashi/101Param*Position 52 mys	Braking	318.75	618.75	Accelerating	465.75	765.75	-0.016776923	Pier 10
53	UIC774Hwashil101Param'Position 53.mys	Braking	325	625	Accelerating	469	769	-0.016730653	Pier 10
54	UIC774Hwashi101Param'Position 54.mys	Braking	331.25	631.25	Accelerating	472.25	772.25	-0.016755321	[Pier 10
55	UIC774Hwashil101Param*Position 55 mys	Braking	337.5	637.5	Accelerating	475.5	775.5	-0.016772138	Pier 10
56	UIC774Hwashil101Param'Position 56.mys	Braking	343.75	643.75	Accelerating	478.75	778.75	-0.016792597	Pier 10
57	UIC774Hwashil101Param'Position 57.mys	Braking	350	650	Accelerating	482	782	-0.016804825	Pier 10
						1			

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

	0	C C	0	E	-	G	н		1	K
		Check of Longitudinal Relative Displacement	at hetween Ends	of Decks (End.)	Rotations)					
-		citer of congrading for the origination	it bettreen ener	or meeter failer	in a constant of the second seco					
	Job Title:	HC 774-305-stat HC 774Hzash107Param								
	ducia Edenamo:	1877/March/101Darrer/Decking Lash 1877/March/101Darrer	Desition 101							
M	adel Directory	California (1950) Coale Storest referenceation	T SHANT MT							
-	Analysis Date:	28/03/2019> 28/03/2019								
	Madel Heiter	National Contractory								
	Product Center.	nonoga,c								
				Track 1			Track 2			
				Distance from	Distance from		Distance from	Distance from	Beak Bulating	Disc Numb
				Left End of the	Left End of the		Left End of the	Laft End of the	I maitude al	Legation
	Analysis ID	Results Filename	Loading Type	Mandad to the	Madel to the	Loading Type	Madel to the	Mandal an alter	Disclosure hates	E.ocatio
				Station	Finishing		Station	Einishing	Ends of Daraha Basilian	Deebe m
		187774H and 2010 may Pacifican Lana	Temperature Only	Junung	running	Terrena and an Oak	starting	ranning	-1065145-05	Dire 10
		UC770Headel/OParen/Position Lange	Dating		200	Accelerating	100	600	0.00043160	Der 7
_		18777414 and 1978 and 7 Decision 2 more	Budden	6.16	206.25	Accelerating	303.25	603.25	0.000491749	Der 7
		HC774Hearbil/OParam/Position 3 must	Buling	10 0	942.5	Accelerating	304.0	pre c	0.000491996	Plar 7
-	3	10774Masseld/2012 areas Desition disease	Dating	10.75	210.75	Accelerating	308.5	606.5	0.000431836	Der 7
-		117774Harashi/Officiant/Desition Survey	Buling	10.75	310.75	Accelerating	303.15	600.10	0.000492027	Der 7
-	2	187774bb add/2000 area/Decision 6 area	Rubing	25	221.25	Annalusting	210	613	0.000492299	Der 7
-	7	UP 774Ma and 2010 and 7 Cardina 7 and	Rubing	3125	33125	Accelerating	316.20	610.20	0.000552539	Der 2
-		187774Masseld/00Darser/Doction Bases	Baking	01.0	331.5	Accelerating	313.0	613.0	0.000552518	Der 2
-		INCOME IN THE REPORT OF MEMORY POWER OF BUTTER	Ruling	43.75	343.0	Accelerating	3/2/19	844,75	0.000663257	Dur 2
-		UP774bb add/2012 and Position 10 and	Ruling	50	336	Accelerating	200 20	620	0.000746765	Dan 2
-		UIL / 14/14 athe to Planam Position 10. High	Draining	50.25	306.23	Accelerating	323.25	823.25	0.000157124	PHR2
-	11	UP TABLE CHARGE A PRIME POINT TO AND TABLE	Realized	82.5	362.5	Accelerating	332.5	652.5	0.000891738	Dur 2
-	10	UL 7 MIN and D an Poston 12 mps	Diwang	60.75	368.75	Accelerating	335.15	6.0.70	0.000346603	inez .
-	15	UIL / 14/14 athe IO Praram Protition 13. High	Drawing	/5	3/5	Accelerating	335	633	0.000077300	1998.2
-	14	UIL / AHV ashi UIP aram Position 14. mys	Braking	8125	381.25	Accelerating	342.25	642.25	0.000783909	Pierz
_	10	UIL 7 PHHy ashe U Pracam Postion To mos	Braining	07.5	307.5	Noelecating	345.5	045.5	0.0060061	PHEZ
-	16	UIC 7 NHV ashi 101Param Position 16 mys	Braking	33.75	393.75	Accelerating	348.75	648.75	0.000636353	Pier4
	17	UIC774Hvashi101Param/Position 17.mys	Braking	100	400	Accelerating	352	652	0.000707037	Pier 4
_	10	UIC 774Hv ashi/101P at am Position 18 mps	Braking	106.25	406.25	Accelerating	355.25	655.25	0.000784837	Pier 4
_	19	UIC774Hv ashi/IOIP aram Position 13 mps	Braking	112.5	412.5	Accelerating	358.5	6.566	0.000317464	Pier4
	20	UIC774Hvashi101Param/Position 20.mys	Braking	118.75	418.75	Accelerating	361.75	661.75	0.00102237	Pier 4
	21	UIC774Heashil101Param Position 21.mys	Braking	125	425	Accelerating	365	665	0.00106717	Pier 4
	22	UIC774Hvashi101Param/Position 22.mys	Braking	131.25	43125	Accelerating	368.25	660.25	0.001064259	Pier4
	23	UIC774Hv ashi/101Param/Position 23.mys	Braking	137.5	437.5	Accelerating	3715	671.5	0.001042008	Pier4
	24	UIC774Hv ashi101Param/Position 24.mys	Braking	143.75	443.75	Accelerating	374.75	674.75	0.001018645	Pier 4
	25	UIC774Hvashi101Param/Position 25.mys	Braking	150	450	Accelerating	378	678	0.000997577	Pier 4
	26	UIC774Hvashi101Param/Position 26.mys	Braking	156.25	458.25	Accelerating	381.25	681.25	0.000970551	Pier4
	27	UIC774Hv ashi/101Param/Position 27.mys	Braking	162.5	462.5	Accelerating	384.5	684.5	0.000930103	Pier4
	28	UIC774Hv ashi101Param/Position 28.mys	Breking	168.75	468.75	Accelerating	397.75	697.75	0.000874036	Pier 4
	29	UIC774Hv ashi/101Param/Position 23.mys	Braking	175	475	Accelerating	391	691	0.000805822	Pier4
	30	UIC774Hvashi101Param/Position 30.mys	Braking	181.25	481.25	Accelerating	394.25	694.25	0.000798728	Pier 7
	31	UIC774Hv ashi/101Param/Position 31 mps	Braking	187.5	487.5	Accelerating	397.5	697.5	0.000915344	Pier 7
	32	UIC774Hy ashi/101Param/Position 32 mps	Braking	193.75	493.75	Accelerating	400.75	700.75	0.001000933	Pier 7
	33	UIC774Hvashi101Param/Position 33.mys	Braking	200	500	Accelerating	404	704	0.001024163	Pier 7
	34	UIC774Hv ashi/101Param/Position 34.mus	Braking	208.25	506.25	Accelerating	407.25	707.25	0.001000199	Pier 7
	35	UIC774Hv ashi/101Param/Position 35.mys	Braking	212.5	512.5	Accelerating	410.5	710.5	0.000961496	Pier 7
	36	UIC774Hvashi101Param/Position 36.mys	Braking	218.75	518.75	Accelerating	413.75	713.75	0.00093011	Pier 7
	37	UIC774Hv ashi/101Param/Position 37.mys	Braking	225	525	Accelerating	417	717	0.000915701	Pier 7
	38	UIC774Hy ashi/101Param/Position 38.mus	Braking	23125	531.25	Accelerating	420.25	720.25	0.00091589	Pier 7
	39	UIC774Hv ashi/101Param/Position 39.mys	Braking	237.5	537.5	Accelerating	423.5	723.5	0.00092306	Pier 7
	40	UIC774Hyashi101Param/Position 40.mus	Braking	243.75	543.75	Accelerating	428.75	726.75	0.000931649	Pier 7
	41	UC774Hvashi101Param/Position 41 mps	Braking	250	550	Accelerating	430	730	0.000938792	Pier 7
	42	UIC774Hv ashi/101Param/Position 42 mys	Braking	258.25	556.25	Accelerating	433.25	733.25	0.000948236	Pier 7
	43	UC774Hy ashi101Param/Position 43.mus	Braking	262.5	562.5	Accelerating	438.5	736.5	0.000961102	Pier 7
	44	UC774Hvashi101Param/Position 44.mus	Braking	288.75	568.75	Accelerating	439.75	739.75	0.000999631	Pier 10
	45	UC774Hy ashi/101Pacam/Position 45 must	Braking	275	575	Accelerating	443	743	0.001024825	Pier 10
	46	UIC774Hyashi101Param/Position 46 mus	Building	28125	581.25	Accelerating	446.25	746.25	0.001004322	Pier 10
	47	UC774Hyashi101Pacar/Position 47 mus	Braking	287.5	587.5	Accelerating	449.5	749.5	0.001003052	Pier 7
	48	UIC774Hearbit101Param/Position d8 mer	Bulling	293.75	593.75	Accelerating	452.75	752.75	0.000992239	Der 7
-	43	UC774Heashi101Pacan/Position 49 mut	Building	300	600	Accelerating	456	756	0.000964296	Pier 7
-	50	18C774Hearth/101Datast/Doction 50 mer	Braking	308.25	606.25	Accelerating	459.25	759.25	0.000937144	Der 10
-	54	UIC774Hearth/20Paran/Postion 51 mar	Bulling	949 E	642.6	Accelerating	4010	765 6	0.000040939	Der 10
-	62	187774Hz add/2010 acar/Doction 52 mor	Buling	312.5	610.2	Accelerating	406.0	206.5	0.000945335	Der 10
-	52	UPC774H and 104D and 10 and 10 and 10	Ruling	310,75	010.71	Analysing	400.10	100,10	0.0003532	Der 10
-	50	UK 1 PH Manual And Plant Protection 53, mgs	Ruling	365	0.0	Accelerating	403	763	0.0003555025	Der 10
-	54	UIL CHITV ASHI M HIARAM POSICIO 54 mys	Or seing	33125	63125	reconnecting	472.25	112.25	0.00054255	INK N
_	55	Unu o rente aste to er anam in control 55 most	Creeng	337.5	637.5	ncoelerating	4/5.5	775.5	0.00.09539	I'rer m
		11 RE 17 OM NUMBER OF THE REPORT OF A DESIGN AND A DESIG	1231 84 30-0	1 343.75	0 643.75	EBCOMMING.	1 478.75	1 778.75	0.000052797	1MM TE
-		USCONT AND A CONTRACT OF A CONTRACTACT OF A CONTRACT OF A CONTRACT OF A CONTRACT OF A CONTRACT OF A	O Li						0.0000	10.00

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

	B	С	D	E	1	G	н	1	J	K
		<b>Check of Longitudinal Relative Displace</b>	ment between Ends	of Decks (Total	Effects)					
_										
	Job Title:	UC 774-3 Model UC 774Hv ashi101Param	(D - 4)							
Analy	sis tilename:	UIC / /4Hv ashifU1Param Position 1> UIC / /4Hv ashifU1P	aram Position 101							
Mor	del Directory:	C:#httpects%/12504/TrackStructureInteraction								
	nalysis Date:	2003/2019> 20/03/2019								
	Model Units:	N.m.kg.s.C								
				Track 1			Truck 2			
				Distance from	Distance from		Distance from	Distance from	Peak Pelating	Disc Number
				Lot End of the	Left End of the		Left End of the	Laft End of the	I engitudie al	Legation
1	Analysis 10	Results Filename	Loading Type	Model to the	Model to the	Loading Type	Madel to the	Model to the	Displacement hetwoon	Supportin
				Station	Finishing		Starting	Finishing	Fods of Backs Positing	Decks wit
	1	UC774Heathil01Patan/Position Lovat	Temperature Only			Temperature Only			-0.014516705	Piec 10
		LIC770HearbilD/Paran/Position Lover	Baking	0	300	Acceleration	300	800	-0.03443652	Pier 10
	2	UC774Hy ashi/01Paran/Position 2 mus	Braking	6.25	306.25	Accelerating	303.25	603.25	-0.0144403	Pier 10
	3	UC774Hv ashif0/Paran/Position 3 mus	Braking	12.5	312.5	Accelerating	306.5	606.5	-0.014444847	Pier 10
		187774Hearbd101Paran/Portion-4 mur	Brakton	1875	318.75	Acceleration	309.75	809.75	0.03444795	Per 1
		LIC778Hearbit01Paran/Position5 mut	Bakkog	25	325	Acceleration	313	613	-0.01445341	Pier 10
	6	LICT/MHvashill/Param/Position6 mus	Building	3125	331.25	Acceleration	316.25	616.25	-0.0345533	Pier 10
	2	18"77dHe seld@1"Param"Dorition 7 mar	Bullion	3125	397.5	Acceleration	319.5	619.5	-0.01465732	Pier 10
1		11CT70Hearb200Param/Position/8 mar	Bullion	43.75	343.75	Acceleration	322 75	622 75	-0.03445787	Pier TI
		18"77.0th sch 20"Daras Decision 3 mer	Bulling	40.10	350	Acceleration	926	676	-0.014477930	Rev TO
-		18"77/84 sel-2012 score Decision 10 mart	Bulling	56.25	350	fooder sting	320	629.25	-0.03498248	Rev 10
+	10	18 770Hz and 2012 as an Provision 11 mar	Building	62.5	336.23	Acceleration	323.25	6325	-0.01435245	Re D
-	11	18 TRAL and ROTE and Poster 12 and	(halles	62.5	362.5	Annalization	332.5	632.5	-0.04537000	0
-	12	1877744 and 2019 and 2019 and 20	Dubling	30.15	375	free locations	320.15	629	-0.04556556	0-10
+	13	1877/dda and 2019 Param (Paratism Manual	Dealities	01.25	315	Acceleration	333	642.25	-0.0N000000	D=10
-		1 POTTALL AND PARTY OF AN AND A STATE OF A STATE	(De store)	67.6	301.20	Annahing	342.25	042.25	-0.014573161	0
+	10	187724bb and 2010 and 20 participation of the	Pulling .	0/5	307.5	Anning	345.5	045.5	-0.014620693	0
+	10	187724bb ask 8050 Parent Parties 17 million	Putter	30.15	333.15	Annenaling	340.15	646.75	-0.0H620683	010
-	10	1 POTTO ALL ADDRESS OF ALL ADDRESS O	0.000	100	400	moreeding	356	050	-0.01465 H35	0
-	10	Liter Trans assess in an in outside 18 million	Crashg Roddag	106.25	406.25	noceerating	355.25	655.25	-0.04697601	Our D
-	10	Line Transie and the second se	(Participal Contraction of the c	112.5	412.5	noceeraling	300.5	000.5	-0.09473033	0
-	20	URL 11 W as HILL Param Postion 20 mys	Drawing .	18.75	418.75	nuceersting	361.75	001.75	-0.0%779451	C ALL D
-	2	UK, I NEW ASHID Param Position 21 mys	oraking .	125	425	nocererating	365	665	-0.05486285	Pierr
-	22	UIC T14PW ashift0 Param Position 22 mys	Draking	131.25	631.25	Accelerating	368.25	668.25	-0.0150645	Miel T
-	23	UIL FRAM ashirti Param Position 23 mys	Draking	137.5	437.5	Accelerating	3715	6715	-0.015276157	Pier r
-	24	UIL FRAM ASHED Param Position 24 mys	traking	143.75	443.75	Robererating	374.75	674.75	-0.015507631	Pierr
-	25	URL I HITW ASTRID P &r am Position 25 mys	Draking	150	450	receierating	370	670	-0.015724946	Prier T
-	26	UIC 174Plv ashift0 Plaram Position 26 mys	Braking	156.25	456.25	Accelerating	381.25	681.25	-0.015875632	Mier T
-	27	UIL / (4Ph ashifU Param Position 27.mys	Braking	162.5	462.5	Accelerating	384.5	684.5	-0.015991812	Piec r
-	28	UIC 774Hv ashi10 Param Position 28 mys	Braking	168.75	468.75	Accelerating	387.75	687.75	-0.016089043	Pier 7
+	29	UIC 774PN ashift0 Param Position 29 mys	Braking	175	475	Accelerating	391	691	-0.016179056	Pier 7
	30	UIL 1/4Hv ashi/101Param/Position 30 mys	Braking	181,25	481.25	Accelerating	394.25	694.25	-0.016031874	Mer 7
	31	UC774Hv ashi101Param/Position 31 mys	Braking	187.5	487.5	Accelerating	397.5	697.5	-0.015886542	Pier 7
	32	UIC 774Phy ashirt01P aram Position 32 mys	Braking	193.75	493.75	Accelerating	400.75	700.75	-0.015824457	Pier 10
	33	UIC 774Hv ashi/101Param/Position 33.mys	Braking	200	500	Accelerating	404	704	-0.016007188	Pier 10
	34	UC774Hvashi101Param/Position-34.mys	Braking	206.25	506.25	Accelerating	407.25	707.25	-0.016212681	Pier 10
	35	UIC174Hwashil101Param/Position-35.mys	Braking	212.5	512.5	Accelerating	410.5	710.5	-0.016429718	Pier 10
	36	UC174Hvashil01Param/Position-36.mys	Braking	218.75	518.75	Accelerating	413.75	713.75	-0.016645677	Pier 10
	37	UCT74Hvashi101Param?Position.37.mys	Braking	225	525	Accelerating	417	717	-0.016832891	Pier 10
	30	UCT74Hv ashif01P aramPosition 38.mys	Braking	231.25	531.25	Accelerating	420.25	720.25	-0.01636363604	Pier 10
	39	UCT74Heashi101Param/Position 33.mys	Braking	237.5	537.5	Accelerating	423.5	723.5	-0.017070087	Pier 10
	40	UICT74He ashi101Param/Position-40.mys	Braking	243.75	543.75	Accelerating	426.75	726.75	-0.017150945	Pier 10
	41	UIC774Hy ashil101Param Position 41.mys	Braking	250	550	Accelerating	430	730	-0.017220013	Pier 10
	42	UC774Heashil0/Param/Position-42.mys	Braking	256.25	556.25	Accelerating	433.25	733.25	-0.017036363	Pier 10
	43	UIC774Hv ashif01Param/Position-43.mys	Braking	262.5	562.5	Accelerating	436.5	736.5	-0.01684313	Pier 10
	44	UIC774Hv ashi101Param/Position-44.mys	Braking	268.75	568.75	Accelerating	439.75	739.75	-0.016632424	Pier 10
	45	UC774Hv ashif01Param/Position-45.mys	Braking	275	\$75	Accelerating	443	743	-0.016479412	Pier 10
1	46	UIC774Hv ashit01Param/Position-46.mys	Braking	281.25	581.25	Accelerating	446.25	746.25	-0.016337	Pier 10
1	47	UIC774Hv ashift01Param/Position-47 mvs	Braking	287.5	587.5	Accelerating	449.5	749.5	-0.016236206	Pier10
	48	UC774Hvashi101Param/Position-48.mys	Braking	293.75	593.75	Accelerating	452.75	752.75	-0.016133433	Pier 10
	49	UC774Hvashi101Param/Position-43.mvs	Braking	300	600	Accelerating	456	756	-0.016037539	Pier 10
	50	UCT74Hwashill01Param/Position/50.mvs	Braking	306.25	606.25	Accelerating	453.25	758.25	-0.015355282	Pier 10
	51	UCT74Hvashi101ParamPosition51.mvs	Braking	312.5	612.5	Accelerating	462.5	762.5	-0.015083160	Pier 10
	52	UCT74Hy ashif01Param/Position 52 mvs	Buking	318.75	610.75	Accelerating	465.75	765.75	-0.05823722	Pier 10
	53	UCT74Hy ashi101Param/Position 53.mvs	Breking	325	625	Accelerating	453	769	-0.015775627	Pier 10
	54	LICT7dHy ashim Param Position 54 mer	Braking	331.25	631.25	Acceleration	472.25	772.25	-0.015801025	Pier 10
		UC776Heash/00Param/Position 55 mer	Baking	237.6	£37 E	Acceleration	475.5	775.6	-0.05010230	Pier 10
	56	18"774Hearbil0"Param/Position 56 mil	Brakton	343.75	643.75	Acceleration	478 75	778 75	-0.0158404	Per 11
_		187774bb ask #01Page/Pageting 57 min	in strig	342.10	660	a state	410.10	792	-0.045955452	0-10
			10114100			I ACCINE MID A				

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

	B	0	C	F	F	6	н			
	0	Charle of Vention Relation Displacement	at heteres Fusie of Des	der te	,	0	0		4	
-		Check of Vertical Kelative Displaceme	nt between Ends of Dec	:K\$						
	lah Titlar	LIC 774-2 Model LIC 774Mandel 100D state								
Analysis Fi	ilename:	UC774Hvashi10/Param/Position 1> UC774Hvashi1	Param/Position 101							
Model D	frectory:	C+Projects/J12504/TrackStructureInteraction								
Analy	sis Date:	05/06/2017> 08/06/2017								
Mod	lel Units:	Nm.kg.s.C								
				Track 1			Track 2			_
				Distance from	Distance from		Distance from	Distance from	Peak Belative Vertical	
				Left End of the	Left End of the		Left End of the	Left End of the	Displacement between	Pier
A		Decede Eterano	London Trees	Model to the	Model to the	London Trees	Model to the	Model to the	Ends of Decks. Positive	Sup
Penalty	3510	rsesure ritename	Coading Type	Starting	Finishing	Loading Type	Starting	Finishing	higher than proving	Decks
				Position of the	Position of the		Position of the	Position of the	Negative = Nest deck /	Displ
				Loading (m)	Loading (m)		Loading (m)	Loading (m)	abutment lover than	
	1	UC774Hvashil0/Param/Position 1.mvs	Temperature Only			Temperature Only			-8.73504E-08	FHAbu
	1	UIC774Hvashi101Param/Position 1.mus	Braking	0	300	Accelerating	300	600	-7.25557E-07	LH Abu
	2	UIC774Hvashi101Param/Position 2.mus	Braking	6.25	306.25	Accelerating	303.25	603.25	-9.2416E-07	LHAbu
	3	UIC774Heashil101Param/Position 3.mys	Braking	12.5	312.5	Accelerating	306.5	606.5	-100631E-06	LHAbu
	4	UIC774Hvashi101Param/Position 4.mys	Braking	18.75	318.75	Accelerating	309.75	609.75	-9.9023E-07	LHAbu
	5	UIC774Hwashi101Param'Position 5.mys	Braking	25	325	Accelerating	313	613	-9.06053E-07	LHAbu
	6	LIC 774He ashi101P at am Position 6. mus	Braking	31.25	331.25	Accelerating	316.25	616.25	-7.93977E-07	LHAbu
	7	UIC774Hwashi101Param/Position 7.mys	Braking	37.5	337.5	Accelerating	319.5	619.5	-6.92967E-07	LHAbu
	8	UIC774Hvashi101ParamPosition 8.mys	Braking	43.75	343.75	Accelerating	322.75	622.75	-6.2848E-07	LHAbu
		UIC 774Hv ashi10 Param Position 3.mus	Braking	50	390	Accelerating	326	625	3.85903E-07	Pier 2
	10	UIC / remeasing the area measing in the main the single second seco	Draking	56.25	356.23	Accelerating	323.25	623.23	7.7367E-07	HTADU
	11	UIL / (APhy ashi IU Param Position 11 mys	Braking	62.5	362.5	Accelerating	332.5	632.5	7.73555E-07	HPLADU
	12	UK, FININASHIN Param Poston 12, mys	Balling	00.10	300.15	Accelerating	330.79	0.00.13	7.733346-07	DH AL
	10	UC 774M add/00 Param Postori 10.1199	Draking	01 25	20125	Receivating	342.25	642.25	7 700405-07	DH Abu
	15	IN 774Ma adult01Datar/Datation 15 must	Dealing	87.5	307.5	Accelerating	345.5	CAL S	7 795736-07	DHAL
	16	IC776h ashi00Paran/Position 16 mus	Baking	\$3.75	393.75	Accelerating	348.75	648.75	7 783077-07	RHAbu
	17	UIC774Hy ashi10/Param/Position 17.mvs	Braking	100	400	Accelerating	352	652	7.79438E-07	Pier 4
	18	UIC774Hv advil101Param/Position 18 mus	Braking	106.25	406.25	Accelerating	355.25	655.25	7.77573E-07	RHAbu
	19	UIC774Hvashi101Param/Position 15.mys	Braking	112.5	412.5	Accelerating	358.5	658.5	7.77163E-07	RHAbu
	20	UIC774Hvashi101Param/Position 20.mys	Braking	118.75	418.75	Accelerating	36175	661.75	7.76762E-07	RHAbu
	21	UIC774Hwashi101Param/Position 21.mys	Braking	125	425	Accelerating	365	665	7.76375E-07	RHAbu
	22	UIC774Heashi101Param/Position 22.mys	Braking	131.25	431.25	Accelerating	368.25	668.25	7.7597E-07	RHAbu
	23	UIC774Hvashi101Param/Position 23.mys	Braking	137.5	437.5	Accelerating	3715	6715	7.75548E-07	RHAbu
_	24	UIC 774Hvashi101Param Position 24.mys	Braking	943.75	443.75	Accelerating	3/4.75	674.75	7.751062-07	HHADU
-	69	UL / New advito Planar Position 25 mgs	Drawing	150	400	Accelerating	378	678	7.745436-07	CLIAL
-	20	UIL / remeasel U Param Position 20 mys	Draking	100.23	400.23	Accelerating	30125	001.03	7.74203E-07	HIT ADU
-	28	IF 774Headel00Param/Destine 28 mil	Baking	96.75	468.75	Accelerating	387.75	687.75	7 73275-07	DHAbu
-	29	IIC776Headel10 Param Decking 29 mar	Braking	175	400.10	Acceleration	391	691	8 350265-07	Pier 7
	30	UC776Hrashil0/Paran/Position 30 mis	Baking	101.25	401.25	Acceleration	394,25	694.25	7.71758-07	FHAhu
	31	LIC774Hy ashi101Param/Position 31 mus	Building	107.5	487.5	Acceleration	397.5	697.5	7.70887E-07	FHAhu
	32	UIC774Hvashi101Param/Position 32 mvs	Braking	193,75	493.75	Accelerating	400.75	700.75	7.70045E-07	RHAby
	33	UIC774Hv ashi101Param/Position 33.mys	Braking	200	500	Accelerating	404	704	7.69293E-07	RHAbu
	34	UIC774Hvashil101Param/Position 34.mys	Braking	206.25	506.25	Accelerating	407.25	707.25	7.68525E-07	RHAbu
	35	UIC774Hvashi101Param/Position 35.mys	Braking	212.5	512.5	Accelerating	410.5	710.5	7.67773E-07	RHAbu
	36	UIC774Hv ashil101P aram Position 36.mys	Braking	218.75	518.75	Accelerating	413.75	713.75	7.67023E-07	RHAbu
	37	UIC774Hvashil101Param/Position 37.mys	Braking	225	525	Accelerating	417	717	7.662412-07	RHAbu
	38	UIC774Hvashi101Param/Position 38.mys	Braking	231.25	531.25	Accelerating	420.25	720.25	7.65359E-07	RHAbut
	39	UIC774Hvashi101Param/Position 33.mys	Braking	237.5	537.5	Accelerating	423.5	723.5	7.64466E-07	RHAbu
_	40	UIC 7 74Phy ashift01Plaram Position 40.mys	Braking	243.75	543.75	Accelerating	425.75	726.75	7.635612-07	HHADU
	41	UIC 7 4Phy ashift Param Poston 41 mys	Braking	250	550	Accelerating	430	730	8.30904E-07	Pier 10
	42	UIL CINEW ASNITU Param Position 42, mys	braving	230.23	300.43	HCOEleraing	433,25	133.63	7.655006-07	HITHOUT
	43	UL 7 New ashi to Param Position 43 mgs	Draking	202.0	562.5	Accelerating	430.0	730.5	7.755022-07	PIPIADU
	45	UL 7 Perio april 0 Param Poston 49 mgs	Balana	200.75	560.75	Accelerating	*33.75	133.15	7.07200E-07	DHAL
-	45	UK 11% Washing Param Position 45.095	Baking	20125	5/5	Accelerating	445	746.25	7.322046-07	BHAM
-	40	11774Headbill01Deam/Deation 47 mus	Braking	201.20	587.5	Accelerating	449.5	740.25	-7.565525-07	I HAN
	48	III 774He adult 11 Day on Darking d8 mut	Braking	293.75	593.75	Acceleration	452.75	752.75	-7.567395-07	IL HADLA
	49	IF 774th adult/IP aren Destrice 49 mus	Baking	200.10	600	Acceleration	456	756	-7.360952-07	I H Abu
	50	UC774Hyashi101Param/Position 50 mus	Baking	306.25	EDE 25	Accelerating	459.26	75.9.26	7.166995-07	RHAL
	51	LIC776Hyashill/Param/Position S1 mus	Braking	312.5	612.5	Acceleration	462.5	762.5	8.65324E-07	RHAbu
	52	UIC 774Hv ashi107P aram Position 52 mus	Braking	310.75	618.75	Accelerating	401.71	765.75	115734E-06	FIHAbu
	53	UIC774Hvashi101Param/Position 53.mus	Braking	325	625	Accelerating	469	763	159266E-06	RHAbu
	54	UIC774Hvashi101Param/Position 54.mvs	Braking	331.25	631.25	Accelerating	472.25	772.25	1.6751E-06	RHAbu
		I REAL AND A	10 L	227.0	637.6	Annalasia	470.0	775.0	1077.00	Phi Aker

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

8	C	D	E	F	G	н	1	J	K	
	Check of Longitudinal Reactions									
Job Title:	UIC 774-3 Model: UIC774Hvashi101Param									
Analysis Filename:	UIC774Heashi101Param/Position 1> UIC774Heashi101Param/Pos	Non 101								
Model Directory:	C:IProjectsU12504\TrackStructureInteraction									
Analysis Date:	28/03/2019> 28/03/2019									
Model Units:	N.m.kg.s.U									
			Track 1	0		Track Z	0			÷
			Distance from	Distance from		Distance from	Distance from	Peak	Abutment / Pier	
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	Number with	
			Model to the	Model to the		Model to the	Pladel to the	Reaction (N)	Peak Reaction	
-	1 IF 774He add/WP com Position 1 mer	Temperature Dale	orarring	runsning	Temporate an Otda	Statung	rmsning	202462.412	Diart	Ł
	IF 774Ha add O'Param Position 1 mur	Braking	0	300	Annaleration	300	600	249128 734	Dars	F
2	III 774Headel 101Decem Decision 2 mor	Braking	6.25	306.25	Annalyzation	303.25	603.25	244951485	Place 5	Ŀ
3	UIC774Hy ashi/DIParam Position 3 most	Baking	12.5	312.5	Anneleration	306.5	606.5	239183 394	Pier5	H
4	UIC774Headol101Param/Position 4 mut	Braking	18.75	313.75	Appelerating	309.75	603.75	-268712 8429	Pier 1	F
8	UIC774Hwashi101Param'Position 5.ms	Braking	2%	305	Accelerating	313	613	-306729 969	Pier 1	L
a l	UIC774He ashi/101Param Position 6.mus	Braking	31.25	331.25	Accelerating	316.25	616.25	-331727.754	Pier 1	E
7	UIC774Hwashi101Param/Position 7.mut	Braking	37.5	337.5	Accelerating	319.5	619.5	-350305.303	Pier 1	
i i	UIC774Hwashi101Param'Position 8.mss	Braking	43.75	343.75	Accelerating	322.75	622.75	-370518.4442	Pier1	1
9	UIC774Headh/101Param/Position 3.mus	Braking	50	350	Accelerating	326	626	-332065.1678	Pier 1	
10	UIC774Hy adu/101Param/Position 10 mus	Braking	56.25	356.25	Accelerating	329.25	629.25	-395055.8483	Pier 1	
11	UIC774Heash101Param'Position 11mes	Braking	62.5	362.5	Appelerating	332.5	632.5	-395802.4265	Pier1	Ľ
12	UIC774Headul101Param/Position 12.mus	Braking	68.75	368.75	Accelerating	335.75	635.75	-450938.891	Pier 3	Г
13	UIC774Heashi101Param/Position 13.mus	Braking	75	375	Accelerating	339	639	-527890.0365	Pier 3	Г
14	UIC774He ashi101Param'Position 14.mys	Braking	81.25	38125	Accelerating	342.25	642.25	-591623.637	Pier 3	Г
15	UIC774H#ashi101Param'Position 15.mys	Braking	87.5	387.5	Accelerating	345.5	645.5	-649542.530	Pier 3	
16	UIC774Hwashi101Param'Position 16.mys	Braking	93.75	393.75	Accelerating	348.75	648.75	-707463.881	Pier 3	
17	UIC774He ashd101Param*Position 17.mys	Draking	100	400	Accelerating	352	652	-763144.931	Pier 3	
18	UIC774Hwashi101Param/Position 18.mys	Braking	106.25	406.25	Accelerating	355.25	655.25	-786742.766	Pier 3	
19	UIC774Hwashi101Param'Position 13.mys	Braking	112.5	412.5	Accelerating	358.5	658.5	-804821783	Pier 3	
20	UIC774He ashd 101Param Position 20.mys	Draking	110.75	410.75	Accelerating	36175	661.75	-010003.335	Pier 3	L
21	UIC774Hwashi101Param'Position 21.mys	Braking	125	425	Accelerating	365	665	-832402.885	Pier 3	
22	UIC774Hwashi101Param*Position 22.mys	Braking	131.25	43125	Accelerating	368.25	668.25	-848416.261	Pier 3	L
23	UIC774He ashi/101Param/Position 23.mys	Braking	137.5	437.5	Accelerating	3715	6715	-852138.438	Pier 3	L
24	UIC774Hwashi101Param'Position 24.mys	Braking	143.75	443.75	Accelerating	374.75	674.75	-871871.524	Pier 3	L
25	UIC774Hwashi101Param*Position 25.mys	Braking	150	450	Accelerating	378	678	-880195.3963	Pier 3	L
26	UIC774Heashil101Param/Position 26.mys	Braking	156.25	456.25	Accelerating	38125	681.25	-894155.953	Pier 3	L
27	UIC774Hwashil101Param/Position 27.mys	Braking	162.5	462.5	Accelerating	394.5	684.5	-308728.3568	Pier3	Ł
20	UIC / 14Phe ashel IUIP aram Position 28.mys	braking	168.15	468.75	Accelerating	381.75	667.75	-322363.815	Pier 3	Ł
23	UIL / (4He ashi IUIParam Position 23.mys	braking	1/5	4/5	Accelerating	391	691	-9355913728	Plet 3	ŀ
30	UIC / NHW ashint/Theram Position 30 mgs	Draking	101.25	68125	Accelerating	394.25	634.25	-333465.5555	Pier3	Ł
31	UIC 714He aire Dir aram Position 31 mys	Drawing	101.5	407.5	Accelerating	337.5	200.75	*330 86.358	Piero -	Ł
36	UIL / HARASHI DIParam Postion 32 mys	braing	103.15	433.75	HOOMERAING	400.75	100.15	-324013.564	Piero	ŀ
33	UIC / HYPerane DiParam Position 33.mys	Drawing	200	500	Noceterating	404	704	-025333.057	Piero	ŀ
34	UIC 7 1919 all 90 Param Position 34 Mys	Dializa	206.25	500.25 Et2 E	Accelerating	407.25	7107.25	-930937-255	Der 2	ŀ
1 22	UNCTIMINATION PARTY Description 20 month	Baling	212.5	512.5	Annalisation	410.5	710.5	-34323.004	Dec 3	ŀ
30	UP 7744 and 200 Param Poster 30.899	Daling	210.15	510.75	franker af rig	413.75	713.75	-047823.004	Direct	H
3/	III 774Ha adult/dDaram/Doction 38 mar	Braking	23125	59125	Acceleration	420.25	720.25	-971371.801	Per 5	F
1 20	I II 774Ha adul Y/Paran/Doubico 39 mar	Baking	237.5	537.5	Appeleration	4215	723.5	-994833.0253	Pier 5	Ŀ
40	UP774He add WWD area /Decision 40 min	Daling	243.75	E42 7E	Accelerating	420.0	716.70	-1000473.478	Der	ŀ
41	III 774He add 10 Param Postion 41 mer	Braking	250	550	Acceleration	490	730	-1035214 78	Plat 8	ŀ
42	IF 77MHz add/07Param/Position d2 most	Baking	256.25	556.25	Appelerating	411.25	711.25	+1051741 252	Piero	Ł
43	IF 774He add O'Param Position d3 mur	Braking	262.5	562.5	Annaleration	496.5	716.5	-1067997.96	Date	Ŀ
44	III 774Headel 101Param Position dd mur	Braking	268.75	568.75	Annalyzation	439.75	719.75	-1081709.025	Place 8	Ŀ
45	IF 774Ma add YOP as an Position d5 mort	Buling	275	575	Anneleration	443	743	-1107705.63	Dies 0	H
46	LIC 774Ha add O'Decar Decision df. mur	Braking	201.25	68126	Annaleration	446.25	746.25	-1132009 536	DetB	F
47	LIC774Hwadel101Param/Position 47 mus	Braking	287.5	587.5	Appelerating	4495	743.5	-1172583.558	Pierß	Ŀ
48	UIC774He ashi/101Peram Position 48 mus	Breking	293.75	593.75	Accelerating	452.75	752.75	-1211179.52	Pier 8	F
49	UIC774Headel101Param/Position 49 mus	Braking	300	600	Appelerating	456	756	-1245385.72	Pier 8	E
50	UIC774Hwashi101Param'Position 50.mvs	Braking	306.25	606.25	Accelerating	459.25	758.25	-1274506.78	Pier8	L.
51	UIC774Hs ashi/01Param/Position 51.mus	Braking	312.5	512.5	Accelerating	462.5	762.5	-1300387.83	Pier 8	E
52	UIC774Hx adul101Param/Position 52 must	Braking	318.75	618.75	Accelerating	465.75	765.75	-1324399.27	Pier 8	
53	UIC774Hwashi101Param'Position 53.mvs	Braking	325	625	Accelerating	463	769	-1346310.15	Pier8	Ľ
54	UIC774Headel101Param/Position 54 mus	Braking	331.25	63125	Accelerating	472.25	772.25	-1358221698	Pier 8	
55	UIC774Hwadhi101Param/Position 55 mut	Braking	337.5	637.5	Accelerating	475.5	775.5	-1369262.065	Pier8	
56	UIC774Hy ashi/101Param/Position 56.mvs	Exaking	343.75	643.75	Accelerating	478.75	778.75	-1372416.668	Pier8	Ľ
57	UIC774Hy ashil 101Param Position 57 mas	Braking	350	650	Accelerating	482	782	-1374216.494	Pier 8	



	0	D	E	F	6	н	1	J	K	L	н	N	0	P	
	Check of Axial Rail Stress														
dah Titla:	USO TTA-109-A-1 USOTTABL-set-2007 areas														
dyris Filenemer	UIC776Harahil191Param*Parities.1 UIC776Harahil191Param	"Parities 91													
adel Directory:	0.1Preject/UI2504/TrackStructuralstarection														
Hadel Baite	No. hours														
			Tresh 1			Track 2									-
			I of End of the	Durtance from		Dutance fram	I of Lad of the	Paul Hart	Treeb Humber	Laft Fad of	·	Paul: Hart	Track Humber	I of End of	•
An electric ID	Reads filmen	Interface Terry	Madel to the	Hadel to the	Landing Trees	Hadel to the	Madel to the	Tearile Aziel	with Pook	Structure for	Description of	Camprorrivo	Marth	Structure for	Dercris
			Starting	Finishing		Starting	<b>Finishing</b>	Stease of Rail	Hart Tearile	Paul Hart	pash Incotion	Aniel Strass of	Ommerassies	Paul Hart	
			Paritian of the	Paritian of the		Parition of the	Parities of the	(HP-4)	547407	Tearile Streer		Real (HP-4)	Stease	Comprossive	
	EUG774Hushill)If eren "Parities Lngs	Temperature Only			Temperature Only			34.54472655		6	8 VPhile Deck 3	-46.04217925		S 8	25 AHAL-VID
	1 UK (COReaster) The area "Parties Longe	Brahing .		144.15	Acceleration	343.10	600	24.45256254		10	N Webble Duck 2	-8.445210		1	1 10 10 10
	2 UKC774HumbilthTP aren "Parities 3 myr	Brahing	8.5	242.5	Assalurating	201.8	686.5	34.45422444		10	6 Vinius Durak 2	-45.69325629		1 3	S RHAL
	UI0774HoubilthPeron/Parities4.nyz	Draking	91.75	218.72	Accolumating	399.75	649.75	34,45447334	2	10	5 VRNix Duck 3	-45.55590004		2 23	24 Within Du
	6 UIC 77 (Husefull) IP er on "Parities 5 myr	Braking	25	325	decoloration	213	60	26.44914624		10	5 Vittin Durch 3	-45.64915(19		9 24	24 Vistin D.
	6 UIC 774Huarbitt91P er an "Paritian 6 myr	Draking	2125	2212	Accelerative	298.25	616.25	34,40492492		0	S VINNa Duck 2	-45.64752267			De VOLLO
	1 UI0774Hashi191Peren "Parities Love	Prehing	40.75	242.75	Asseleration	322.75	622.75	26.4044225		10	S Vibbis Dusk 2	-5.1415917			Sel Visitin De
	UIC774Hushill)IP eron "Parities 1 mur	Braking	51	354	Accelerating	224	626	35.45424522	2	1 13	S WHININ Durch 3	-45.74591275		34	a within De
	9 UE0774Hunahi3998Farans"Parisian.56.expr	Draking	94.25	3\$4.25	Accelerating	229.25	629.25	26.20644259	2	10	S VINUs Du ek 2	-65.57997655			Te VOLAND
	EURO Freihunghamp Provins Parities 10, mar	Breiting	62.5	342.5	Accelerating	332.5	632.5	34.37704043		9	5 VPhis Duck 3	-47.62999402			Tel Stekas Da
	The second second second second second	Baching	10.10	110	Anniherming	110	474	14 348.4377			P Markin Durch 7	-10.2712412			and the state of the
14	CURC 774Harahilth Paran "Paritian Manar	Deathing	\$1.25	211.25	Assalutating	242.25	642.25	24.32742444		10	S Vibble Dunk 2	-50.45270481			en Plant
	5 UICT14Numhilt91Foron/Facilian 15 m yz	Draking	07.5	347.5	Accolurative	345.5	145.5	34.34792995	2	10	D Vikhis Duck 3	-51,71420624			en statis De
1	UIC ( ( Muselul II) Faran "Faritan Sury	Braking	92.79	242.19	deeslarating	341.16	648.75	26.22299416		19	D Vielus Durch 2	-94.94019940		1	an Diskin Da
	EUROT764 and EDTF and "Parities St. Aug	Brabing	940.20	400	Assalutation	246.24	655	26.32662433		8	S Minin Durch 2	-54.90510957			Tel Statio D.
	1 UI0774Harahil1991Foron "Parities 19 Jays	Draking	10.5	40.1	Accolumnia	251.5	151.5	>1.54274912		0	H Within Duck 2	-56.54700520			Te Vistin De
21	BUIC774Huarhi199Peron "Parities 28.mor	Braking	111.79	411.25	Accelerations	361.75	651.79	36.70625211		10	of Within Durch 3	-51.12395124		( r	Te Vistin De
2	1010774Harahil991Peron/Parities21.np	Draking	23		Accolutating	36	445	24.0050292	2	2	Minis Duck 2	-59.64229626		1 5	Tel Visit Du
21	EUROTORian Million on Traction 22 May	Bratting Desking	013	013	Acosturations	359.25	648.25	34,67939887			Within Duck 3	-11124-0998		1 1	TE Dire 7
24	EUGT/Muschill/Press/Parities24.pvr	Braking	10.75	443.75	Acceleration	114.75	574.75	35 50014173		10	3 Mithia Deck 3	-14.20204836			The last
21	S UI0774Harahilth/IP aran "Paritian 25 myr	Drahing	151	61	Accelerating	278	671	35.12525425	2	10	O VINUe Duck 2	-65.52245245			15 Piur 7
24	5 URC 774Hurachil1971F or on "Fazition 25. mor	Braking	196.25	495.25	Accoluration	39125	691,25	35.00990113	2	10	3 VENIx Deck 3	-\$5.51219919			79 Piles 7
21	PUIC774HarahilthTP aron "Paritian 27 mor	Brahing	912.5	462.5	Assalurating	224.8	684.5	25.4509977		10	Minis Dunk 2	-47.43290000		4 4	Tel Vista Da
2	NUTLY THE AND THE ADDRESS OF THE ADDRESS AND THE ADDRESS ADDRES	Breine	10.12		Acceleration	207.15	647,12	26.25486.201		10	Million Duck 2	44 12722045		1 2	Tel Million Du
21	100774Hurshilt01Foron "Farition 38 mor	Draking	91125	491.25	Acceleration	29425	694,25	34,22400992		0	WHILE Duck 2	-10.59115427		e e	Te Within Da
31	USC774Harachill)1P or on "Paritian 31, nyy	Brabing	112.5	417.5	Accelerating	297.6	647.5	24.26322944		10	Within Durch 3	-17.84910292		1	Te vistin D.
23	2 UI0774Howhilth1Peren "Parities 32 mor	Draking	193.75	492.75	Accolumating	499.75	766,75	36.27407796		0	H Vikhis Duck 2	-67.99216772			15 Pier 7
11	DUIC // Hushill/IP eren "Parities II. Por	Braking	200		decouration	444	704	34.27791424		10	Webus Durch 3	-44.29017044			The Place T
19	1000 CONTRACTORY of the Partial Delay	Braking	29.5	10.1	Acceleration	40.5	718.5	34.20495105		1 10	of Within Duck 2	-17.1070645			Re Play 10
24	6 UI0774Harahilth/IP aran "Paritian 36 myr	Draking	240.75	\$10.75	Accelerating	40.75	710.75	26.56249992		0	Miklis Duck 2	-69.1442224		2	St Piur St
31	TUICTIVHushill)IP er en "Parities 37. nor	Braking	225	525	Accoluteting	417	111	35.80149222	,	19	WHINE Duck 3	-14.0707		25	58 Pice 10
21	8 UE0774HarachiH91P or on "Paritian 28 mor	Drahing	224.25	\$21.25	Assolutions	420.25	724.25	24.0476.994		1 10	2 Viblis Du +k 2	-78.00242711		21	ER Plan SO
	NUTO TT PLANT TO TT AT THE STATE OF A PLANT	Desting	2013	60.1	Accelerations	425.5	712.5	34,42505520		0	2 Million Double 2	-72 41225.265			Call Statis
	100770Hushilth and Tarities dia or	Braking	250		Acculateting	428	716	48.39559447			O Mithin Durch 3	-72.45516.064		21	CT STATE OF
4	2 URC774Harachill/IP ar an "Paritian 42 mor	Brabing	294.29	\$\$4.25	Assalurating	422.25	722.25	41.00555.422	2	10	12 Viblue Du +6 2	-72.24444545		i î	es votin De
•	010774BuschillelPeren "Parities 43.myr	Draking	242.5	542.5	Accelerating	434.5	734.5	41.66841144		104	Within Dack 3	-11.5-04-9969		24	en stitlin Du
*	GIC//dhushill/Feran Faritan 64 nor	Braking	241.79	HL N	decelorating.	494.05	139.19	41,29239624		10	Within Duck 3	-79.717934%		9 8	seprice so
	State of the second state	Baching	215.20	411.0	Assolution	44.35	745.35	20.72005577			Within Deck 2	20 7252343		1 1	Del Marken D.
4	7 UE0774Harahilt01P or on "Paritian 47. nov	Draking	207.5	\$17.5	Accelerating	449.5	749.5	20.25454105		10	7 Within Duck 2	-72.22007545		2	De Vistin Du
4	EUIC774Hurshill/1Peron "Parities 48.mor	Braking	2+3.79	\$13.75	Accoluteting	452.75	192.75	37.84399319		1 13	H WHINE Duck 3	-73.994444431		1 14	24 Vinhin Du
-	1 UI0774Harahil991Peran "Paritian 49 myr	Draking	200	600	Accelerating	454	794	22.70658975	2	0	K White Duck 2	-74,74549292		1 2	24 VOLD
	RUIG FERHURS IN Press Parities 51 Ave.	Braking	199.25	40.1	Accelurations	40.0	199,25	37.52734134			Minis Deck 3	-19,77620411			Call Makes Do
	USC70Huschill01Foren 7Facilian 12 pvr	Braking	351.79	A11.75	Acculatering	455.75	76.5.75	37.20526431		13	Statis Deck 3	-77.545579.3		1 1	A MARKIN BA
51	2 UI0774Harahil991Paran "Paritian \$2.myr	Brahing	325	625	Assolution	46.9	764	27.28425462	2	0	S Willia Dunk 2	-79.22722176		1 21	De VOLLO
54	CITOTTellwarhilloff or on "Facilian 54 mor	Braking.	221.25	431.25	Accoluration	472.25	172.25	37.9647227		10	O VIRNis Durck 3	-70.31497264		9 21	Selvin D.
	BUICTINHarahi1991Farah "Paritian \$5.e.ur	Brahing	222.5	622	discolurations .	476.6	775.5	27.50011162		10	D Villia Du ek 2	-11.47724661		1 2	Dental De
51	200077dHuashi1111Param "Paritian \$2.mur	Brabing	340.19	140.0	desalaration	410.13	745	27.5627444.4		6	S Vibbin Dunk 2	-72.415.414.4		1 0	re votion.
51	1 UROTT-Hurahilibilt or on "Parities \$1. mor	Draking	294.25	191.25	Accoluration	495.25	115.25	27.14793193		0	WHINE Duck 2	179.5330404		2	a stable De
	©UIC774Hurshill91Peron "Parities \$5.mor	Braking	342.5	662.5	Accelerating	411.5	711.5	37.56433443		10	S Minis Duck 3	-79.53297254		( X	apristin D.
61	Porto r retroansi 101P or on "Parisian 68 mor	Draking	244.75	668.78	Acceleration	491.75	191.75	37.17245564	-	1	D Within Duck 2	-79.52473475		1 2	Constant of
	200776Harshild/Paran /Parkin 52 ave	Deshing	2112	49120	Assolution	419.25	799	27.24727582		0	C Mithia Dunk 2	118.463219921		24	of stable De
43	3 UICT/Mushill/IP or on "Parities 53 mor	Braking	347.5	647.5	Accolurations	501.5	891.5	37.22511992		6	S Within Durch 3	-71.41445254		1 3	a statin De
	UI0774Hawki199Paran/Parities.64.expr	Dealling	292.75	642.75	Accelerating	\$14.75	004.75	27.24046452	2	10	S WAREDuck 2	-79.34222500		4 33	De VOLLO
55	5 UICTNHushill01Peran "Parities \$5.nor	Braking	491	70	Accolutation	500	800	32,50424255	2	29	10 Vibbin Duck 4	-79.32242050		1 2	24 MINEL
41	TUBOTTAN AND THE AND TRACK AND A TRACK AND	Bashing.	494.25	70.5	Academica	51125	011.25	15.00001745		21	Manual Science Brook of	-11.2479465		1 3	Carlottakin Da
	UIC776Handal191Paran "Paritian \$1.eyy	Brahing	411.75	711.35	Asselerating	914.5	114.3	21.0009025		21	N Within Dunk-4	-71.17467525		1 2	te Webin D.
69	SUICTT4Huahil998 oran "Parities \$5.mor	Brakin-s	43	725	Accoluration	521	421	27,24144792	2	21	W MRNin Durch 4	-78,509(77		1 2	A MINA IN DA
71	#UEC774Hurshill978Faran "Paritian 78.mor	Brabing	40125	721.25	Accelerations	\$24.25	124.25	24.50264852	,	1 10	19 Minhia Durah 2	-79.27249990		9 34	Selvisin D.
T	EUROTT-Houshill/IP or on "Parities TLays	Draking	4015	107.5	Accolumnting	517.5	427.5	29.00147777		9	Within Duck 3	-79.422599947		1 2	WINE D
14	a unu i i venaria i i i i e anu e artien 12 mor	Desking	40.19	10.1	Academica	800.19	338.19	20.00774155			Martin Station Burgh 2	25.1730000		1 0	California P.
14	#UR077dHumhilthTP aren "Parities 74 ever	Brabing	414.25	194.25	Assalutations	\$17.25	137.35	37.4479417			A Minhis Durah 3	-79.8121.4706		1	a visto De
71	S UI0774Harahil191Peran "Paritian 75 mor	Draking	412.5	142.5	Accelerating	54).5	048.5	27.35266474		0	S Wikhis Duck 2	-79.23530405		1 5	Se Within D.
N	GUIGTNHushill/IP or on "Parities 75 mor	Braking	415.79	141.29	Acceleration	943.75	843.75	37.16443272		6	N Vithin Durck 3	-79.36379567		3	equinate De
71	rote consumation Param Parities 72 may	Draking	475	1 778	the coloration	547	047	27.65099024			ny weblie Durck 2	-79.40075551		1	on Visio Da
71	#US0774Harshilt21Paran "Parities 78 ever	Brahing	417.5	112.1	Asselection	\$52.5	192.5	26,80011457		0	5 Vibbis Dusk 2	-79.3279965			e vistis D.
	UICTT4Huahil99Peran "Parities Planor	Braking	493.75	193.75	Accoluration	555.75	154.75	34.95351142		0	5 Vikhin Durck 3	-79.13529527		3	A VIAL
	UIC776Hawhill91Paran "Parition 11.mpr	Brahing	500	500	Assalutating	560	264	26.42154252		1 10	S Within Dunk 2	-72.9972-8125		4 22	of wath D.
82	20101149uani1999Feran /Faritien 82.nov	Draking	591.25	101.25	Accolutation	953.25	(43,25	24.9021941			D VIPhis Duck 3	-78,69176666		3 24	CONTRACTOR OF
10	UI07709 and DIF and Trainin II nor	Braking	90.5	10.1	Acceleration	511.5	166.5	20.101020049		1 1	n webis Dush 4	-76.29195214		1 2	Salabala P.
	EUIC77dHusehilt11Paren "Paritien 15 over	Brabing	591.13	910.0	developeration	515.15	049.13	26.52642422			S Vibbin Durch 2	-77.15144 242		1 0	PENGLA D.
	UI0774Harahilth IF or on "Parities H. Por	Draking	\$21.25	42125	Accoluration	\$75.25	014.25	24.04545957		0	S WHILE Duck 2	-77.1582688		1	a stable Du
11	TUSC774Hurshill)1Peron "Parities 17. nor	Braking	\$37.5	107.6	Accelerations	979.5	174.5	34.701039421	1		S Minis Duck 3	-77.24799244		1 34	a vistin De
*1	1 UI0774Hawhil99Peran/Paritian H. Kyr	Draking	\$40.75	(40.2	Accolumnting	\$92.75	002.75	27.26465792	2	29	O WHILE Duck S	-77.12944753		1 2	Service D.
	The second	1 Property and		. 254							and the second se			- 11	e meren an an Alian Dia

Figure 60: Axial Rail Stress Check 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 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
1		Check of Longitudinal Reactions								
2										
	Job Title:	UIC 774-3 Model: UIC 774Hv ashiP403bParamRal								
	Analysis Filename:	UIC774Hv ashiP403bParamRail-BasicCombs/Position 1> UIC774Hv as	ihiP403bParamRaiH	BasicCombs'Position 5						
	Model Directory:	C:Projects5J12504iTrackStructureInteraction								
8	Analysis Date:	28/03/2019> 28/03/2019								
f	Model Units:	N.m.kg.s.C								
3										
9				Track 1			Track 2			
				Distance from	Distance from		Distance from	Distance from	Deab	Abustment / Di
	Analysis ID	Results Filename / Combination Name	Loading Type	Left End of the Model to the	Left End of the Model to the	Loading Type	Left End of the Model to the	Left End of the Model to the	Longitudinal Beaction (N)	Number vith Peak Beactio
1		UC774HundriD402hDarrenDatt Ranta Camb / Dartition 1 min	Tama and an Oak	Starting Position	Finishina	Townson Oak	Starting Position	Finishina	200462 4121	05
		UCTIVE washing coordinates and an experience of the second s	Public		200	Temperature Citiy	070	670	007007 5700	Piero D
2	-	UC774H ashieved Drage Date Cash /Dation 2 miles	Draking	et 16	300	Accelerating	210	661.00	201201.0100	Piero Divi 2
		UC714HvashiP400ParamhaP0asicCombs Position 2 mys	Draking	925	30125 492 E	Accelerating	J0123	722.5	000017.2753	Pler 3
	3	UICT 14rWashin-4030F aramsar-basic Combs Position 3 mys	Braking	243.75	402.0 543.75	Accelerating	432.5 E19.75	013 75	-1201042 32	Plet 0
	5	LIC77dHyachiPdf?bParanRail-BasicComby?Position 5 mos	Braking	325	625	Accelerating	595	895	-1191058.888	Play 11
7	Basic Combination	Position Tinckuring Sell Vision							262674.6646	Pier 5
8	Basic Combination	Position 2 including Self Weight							-643660.0864	Pier 3
3	Basic Combination	Position 3 including Self Weight							-836174.2286	Pier 3
10	Basic Combinatio	Position 4 including Self Weight							-1214172.798	Pier 8
1	Basic Combination	Position Sincluding Self Weight							-1199972.026	Pier 11
2										
3	Warning: Basic c/	ombinations of nonlinear results are not strictly valid and show	d be used with o	sution						
.4										
-										

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 application. If you click Continue, the application will and attempt to continue.	your phore this error									
	Not enough storage is available to complete this operation HRESULT: 0x8007000E (E_OUTOFMEMORY)).	ation. (Exception									
🔺 Det	ails	Continue									
See the er just-in-time	d of this message for details on invoking (JIT) debugging instead of this dialog box.	1									
System.Ou at Micros at Micros at MSEx at MSEx an dataLal	System DutDfMemoryException: Not enough storage is available to complete this ope at Microsoft VisualBasic CompilerServices.LateBinding LateGet(Dbject o, Type objT at Microsoft VisualBasic CompilerServices.NewLateBinding LateGet(Dbject Instanci at Microsoft VisualBasic CompilerServices.NewLateBinding LateGet(Dbject Instanci at MSExcelLibrary.MSExcelLibrary.generateExcelSeriesMaxMinD ataLabets(Dbject excel an dataLabetsMaxAndMinDnly, Boolean hasDataTable, Boolean dataTableBorderHo										
🔝 Micros	oft Excel	×									
8	Excel cannot complete this task with available resou less data or close other applications.	rces. Choose									
		ОК									

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.

		,			
Analysis		Filename		Open	Remove
Position 1		ManageResults~Position 1.mys		V	Remove
Position 2		ManageResults~Position 2.mys	]		Remove
Position 3		ManageResults~Position 3.mys	]		Remove
Position 4		ManageResults~Position 4.mys	L ]		Remove
Position 5		ManageResults~Position 5.mys	]		Remove
8 	Analysis Position 1 Position 2 Position 3 Position 4 Position 5	Analysis Position 1 Position 2 Position 3 Position 4 Position 5	Analysis         Filename           Position 1         ManageResults*Position 1.mys           Position 2         ManageResults*Position 2.mys           Position 3         ManageResults*Position 3.mys           Position 4         ManageResults*Position 1.mys           Position 5         ManageResults*Position 1.mys	Analysis         Filename            Position 1         ManageResults"Position 1.mys            Position 2         ManageResults"Position 2.mys            Position 3         ManageResults"Position 3.mys            Position 4         ManageResults"Position 4.mys            Position 5         ManageResults"Position 5.mys	Analysis         Filename          Open           Position 1         ManageResults "Position 1.mys         Image Results "Position 2.mys         Image Results "Position 2.mys         Image Results "Position 3.mys         Image Results "Position 3.mys         Image Results "Position 4.mys         Image Results "Position 4.mys         Image Results "Position 5.mys         I

Figure 64: Turning Off LUSAS Management of Results Files



Figure 65: Post-Processor Information Message About Loaded Results

	B	E	n	F	F	6	н	1	, l	K
1		Check of Longitudinal Reactions	-	-		-				
2		circuit of congreatment cuertons								
3	Job Title:	UIC 774-3 Model: ManageResults								
4	Analysis Filename:	ManageResults'Position 1> ManageResults'Position 5								
5	Model Directory:	C:\Projects\J12504\TrackStructureInteraction								
6	Analysis Date:	29/03/2019> 29/03/2019								
7	Model Units:	N.m.kg.s.C								
8										
- 0				Tread 4			Track 2			
0				ITACK I			THE R. L.			
	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	Abutment / Pier Number with
10	Analysis ID	Results Filename	Loading Type	Distance from Left End of the Model to the Starting Position	Distance from Left End of the Model to the Finishing	Loading Type	Distance from Left End of the Model to the Starting Position	Distance from Left End of the Model to the Finishing	Peak Longitudinal Reaction (N)	Abutment / Pier Number with Peak Reaction
10	Analysis ID	Results Filename ManageResults Position 1.mjs	Loading Type Temperature Only	Distance from Left End of the Model to the Starting Position	Distance from Left End of the Model to the Finishing	Loading Type Temperature Only	Distance from Left End of the Model to the Starting Position	Distance from Left End of the Model to the Finishing	Peak Longitudinal Reaction (N) 300463.4131	Abutment / Pier Number with Peak Reaction Pier 5
10	Analysis ID	Results Filename ManageResult/Position 1.mys ManageResult/Position 1.mys	Loading Type Temperature Only Braking	Distance from Left End of the Model to the Starting Position	Distance from Left End of the Model to the Finishing 300	Loading Type Temperature Only Accelerating	Distance from Left End of the Model to the Starting Position 270	Distance from Left End of the Model to the Finishing 570	Peak Longitudinal Reaction (N) 300463,4131 287207.5788	Abutment / Pier Number with Peak Reaction Pier S Pier S
10 11 12 13	Analysis ID	Results Filename ManageResult/Position 1.mys ManageResult/Position 3.mys	Loading Type Temperature Only Braking Braking	Distance from Left End of the Model to the Starting Position 0 162.5	Distance from Left End of the Model to the Finishing 300 462.5	Loading Type Temperature Dnly Accelerating Accelerating	Distance from Left End of the Model to the Starting Position 270 432.5	Distance from Left End of the Model to the Finishing 570 732.5	Peak Longitudinal Reaction (N) 300463.4131 287207.5788 -837800.7498	Abutment / Pier Number with Peak Reaction Pier 5 Pier 5 Pier 3
10 11 12 13 14	Analysis ID	Results Filename Managaffendat "Position Tanya Managaffendat" Position 3 mya Managaffendat "Position 3 mya Managaffendat "Position 5 mya	Loading Type Temperature Only Braking Braking Braking	Distance from Left End of the Model to the Starting Position 0 1625 325	Distance from Left End of the Model to the Finishing 300 462.5 625	Loading Type Temperature Drily Accelerating Accelerating Accelerating	Distance from Left End of the Model to the Starting Position 270 432.5 595	Distance from Left End of the Model to the Finishing 570 732.5 035	Peak Longitudinal Reaction (N) 300463.4131 287207.5768 -837800.7498 -1191050.808	Abutment / Pior Number with Peak Reaction Pier 5 Pier 5 Pier 3 Pier 11
10 11 12 13 14 15	Analysis ID	Results Filename HansgeFeraht/Postion Ings HansgeFeraht/Postion Ings HansgeFleraht/Position Sings	Loading Type Temperature Only Braking Braking Braking	Distance from Left End of the Model to the Starting Position 0 162.5 325	Distance from Left End of the Model to the Finishing 300 462.5 625	Loading Type Temperature Only Accelerating Accelerating Accelerating	Distance from Left End of the Model to the Starting Position 270 432.5 535	Distance from Left End of the Model to the Finishing 570 732.5 895	Peak Longitudinal Reaction (N) 300463,4131 287207.5768 -637600,7458 -1191058,888	Abutment / Pier Number with Peak Reaction Pier 5 Pier 5 Pier 3 Pier 11

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:

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

any geometry and mesh features with the Select Any cursor

□ 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 <sup>□</sup> 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,
- $\Box$  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.

Al	• (? \$	e la							
A	B	c	D	E	F	6	н	1	J
1		Check of Axial Rail Stress for Track 1, Node 1031	X=32.0 Y=0.0	Z=0.0					
2									
3	Job Title:	UIC 774-3 Model: UIC774HwashilP403bParamRail							
4	Analysis Filename:	UIC774HwashilP403bParamRail*Position 1> UIC774HwashilP403bParamRail*Po	osition 5						
S	Model Directory:	C\Projects\J12504\TrackStructureInteraction							
6	Analysis Date:	21.03.19> 21.03.19							
7	Model Units:	N, m, kg, s, C							
8									
9				Track1			Track 2		
				Distance from Left End	<b>Distance from Left End</b>		Distance from Left End	<b>Distance from Left End</b>	Anial Stress of Bail for
10	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)	Track 1, Node 1031 (MPa)
11	1	UIC774HwashilP403bParamRail*Position 1.mas	Temperature Only			Temperature Only			15.45929494
12	1	UIC774HwashilP403bParamRail*Position 1.mys	Braking	0	300	Accelerating	270	570	14.97405452
13	2	UIC774HwashilP403bParamRail*Position 2.mys	Braking	81.25	381.25	Accelerating	351.25	651.25	16.18067722
14	3	UIC774HwashilP403bParamRail*Position 3.mys	Braking	162.5	462.5	Accelerating	432.5	732.5	16.53594593
15	4	UIC774HwashilP403bParamRail*Position 4 mys	Braking	243.75	543.75	Accelerating	513.75	813.75	16.61346017
16	5	UIC774HwashilP403bParamRail*Position 5.mys	Braking	325	625	Accelerating	595	895	16.77890357
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29						0			
30									
51									
02									
24									
14									
22									
17									
98									
29									
40									
н н н н ( / F	al Stress(Trk 1,Node 1025)	Rai Stress(Trk 1,Node 1027) Rai Stress(Trk 1,Node 1031)							•

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.

4	A	В	C	D	E	F	G	Н	1	J	K	L	M	N	0
Ŀ	lob Title:	UIC 774-3 N	Vodel: UIC774HwashilP403	bParamRail											
-															
	Analysis F	ilename:	UIC774HwashiIP403bParam	Rail_Selection	"Position 1.	mys									
1	Analysis D	Directory:	C:\Projects\J12504\TrackSt	ructureIntera	tion\Associa	ited Model	Data\UIC774	HwashilP403	oParamRail_	Selection					
5	Analy	ysis Date:	21/03/20	19											
>	MOC	del Units:	N, m, Kg, S, C												
١.													0.0		
5 <u>1</u>	.:Position 1	1 - Deck Ге	emp (Manual NL)										2:Position	1 - Train Load	
\$				Malua	Maxi	mum	Dist (m)	Malua	Mini	mum	Dist (m)				
1			Disa V (m)	Value	ciement	Noue	Disc(iii)	value	ciement	Nude	100				Dire V
2		-	Disp X (m)	2.04105.05		1913	325	4 1505 05		1238	100				Dice X
2			Disp T (iii) Bet D7 (rod)	4.00305.00		1000	207	4.1366103		1772	200				Disp 1
0				4.20302-06	1241	1001	251	-467366-06	269.4	1001	210	1		-	
5			Fz (N)	80060 2021	2504	1692	251	-2001140.1	2004	1909	207				F+ (N
6			My (Nm)	416626 112	1870	1311	125	.252978.33	2684	1801	287				Mv (N
7			ing (init)	410010.111	1070	1011	11.5	202010.00	2004	1001	207				
-									Rot RZ						
8	dement	Node	Distance (m)	X (m)	Y (m)	Z (m)	Disp X (m)	Disp Y (m)	(rad)	Fx (N)	F2 (N)	My (Nm)	Element	Node	Distance
9	1241	935		0 0	0	(	-0.0053352	6.9234E-08	-2.668E-06	-40000.004	64034.9151	-4702.546	1241	935	
)	1241	937		1 1	0	(	-0.0051353	-2.577E-06	-2.655E-06	-40000.004	64034.9151	-4702.546	1241	937	
L	1248	937		1 1	0	(	-0.0051353	-2.577E-06	-2.655E-06	-120000.01	63922.0081	-14164.091	1248	937	
2	1248	942		2 2	0	(	-0.0049357	-5.196E-06	-2.615E-06	-120000.01	63922.0081	-14164.091	1248	942	
3	1253	942		2 2	0	(	-0.0049357	-5.196E-06	-2.615E-06	-200000.02	63932.5372	-23676.824	1253	942	
4	1253	943		3 3	0	(	-0.0047363	-7.762E-06	-2.548E-06	-200000.02	<b>CP</b> 32.5372	-23676.824	1253	943	
5	1256	943		3 3	0	(	-0.0047363	-7.762E-06	-2.548E-06	-280000.02	63933.0285	-33184.047	1256	943	
5	1256	948		4 4	0	(	-0.0045372	-1.025E-05	-2.454E-06	-280000.02	63933.0285	-33184.047	1256	948	
1	1263	948		4 4	0	(	-0.0045372	-1.025E-05	-2.454E-06	-360000.03	63932.7843	-42691.145	1263	948	
3	1263	951		5 5	0	(	-0.0043383	-1.263E-05	-2.333E-06	-360000.03	63932.7843	-42691.145	1263	951	
3	1267	951		5 5	0	(	-0.0043383	-1.263E-05	-2.333E-06	-440000.03	63932.8089	-52198.353	1267	951	
	1267	952		6 6	0	(	-0.0041396	-1.487E-05	-2.186E-06	-440000.03	63932.8089	-52198.353	1267	952	
	1273	952		ь 6 	0	(	-0.0041396	-1.487E-05	-2.186E-06	-520000.04	63932.8097	-61705.548	1273	952	
	1273	957		7 7	0		-0.0039412	-1.695E-05	-2.011E-06	-520000.04	ьзэз2.8097	-61/05.548	1273	957	
5	1276	957		1 7	0		-0.0039412	-1.695E-05	-2.011E-06	-600000.04	63932.8092	- /12/12.742	1276	957	
•	1276	958		8 8	0		-0.0037431	-1.885E-05	-1.81E-U6	-600000.04	63932.8092	- /1212. /42	1276	958	
2	1282	958		8 8	0		-0.0037431	-1.885E-05	-1.81E-U6	-680000.04	63932.8093	-80/19.936	1282	958	
2	1282	363		2 9 0 0	0		-0.0035452	-2.053E-05	-1.381E-06	-680000.04	65932.8093	-60/19.936	1282	963	
-	1288	963		2 3 10 10	0		0.0033432	-2.033E-05	-1.361E-06	- 760000.05	63332.8093	-20227.129	1288	963	
	1200	964		10 10	0	(	0.0033473	2.1075.05	1 2265-06	940000.05	63932.0095	-50227.125	1200	964	
		364		10 10	0	L L	-0.0033473	-2.13/E-03	-1.0206-06	-040000.05	03332.0095	-33734.322	1293	364	
9	1295	969		11 11	0		-0.0031501	-2 21/E OF	-1 044E-06	-940000 05	62922 0002	-99724 222	1200	969	
o 9 0	1293	969		11 11	0	(	-0.0031501	-2.314E-05	-1.044E-06	-840000.05	63932.8093	-99734.322	1293	969	

## 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.

	A1		• 📀 🦸 🖍 Job Title:												×
	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM 🛓
1															
2															=
3	Model F	Filename:	UIC774HwashilP403bParamR	ail_Selection	.mdl		۵.								
4	Model I	Directory:	C:\Projects\J12504\TrackStru	uctureInteract	tion\										
5	Mo	odel Date:	02/04/2019												
6	Mo	del Units:	N,m,kg,s,C												
7															
8	Envelope -	Tempera	iture and Train (Max)										Envelope -	Temperatu	re and Train (Min)
9					Maxi	num			Minii	mum					
10				Value	Element	Node	Dist (m)	Value	Element	Node	Dist (m)				
11			Disp X (m)	0.0143805		1687	250	-0.0033348		935	0				Disp X (m)
12			Disp Y (m)	0.00039559		978	14	-0.0005523		1655	239				Disp Y (m)
13			Rot RZ (rad)	0.00019162		1913	325	-8.141E-05		1688	250				Rot RZ (rad
14			Fx (N)	182686.394	1462	1066	44	-2104769.2	2714	1819	293				Fx (N)
15			Fz (N)	2435953.25	1614	1159	74	-1232195.8	2374	1614	225				Fz (N)
16			My (Nm)	9516215.75	1614	1159	74	-3754965	2448	1657	240				My (Nm)
17															
18	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 (n
19	1241	935	0	0	0	0	-0.0033348	1.8213E-07	4.3536E-05	48334.695	166476.689	104000.364	1241	935	
20	1241	937	1	1	0	0	-0.0031354	4.3612E-05	4.3242E-05	48334.695	166476.689	104000.364	1241	937	
21	1248	937	1	1	0	0	-0.0031354	4.3612E-05	4.3242E-05	113901.23	168380.233	295707.603	1248	937	
22	1248	942	2	2	0	0	-0.0029372	8.6476E-05	4.2406E-05	113901.23	168380.233	295707.603	1248	942	
23	1253	942	2	2	0	0	-0.0029372	8.6476E-05	4.2406E-05	152798.771	168179.568	473568.153	1253	942	
24	1253	943	3	3	0	0	-0.0027403	0.00012825	4.1067E-05	152798.771	168179.568	473568.153	1253	943	
25	1256	943	3	3	0	0	-0.0027403	0.00012825	4.1067E-05	169278.389	168175.387	638798.438	1256	943	
26	1256	948	4	4	0	0	-0.0025445	0.00016846	3.926E-05	169278.389	168175.387	638798.438	1256	948	
27	1263	948	4	4	0	0	-0.0025445	0.00016846	3.926E-05	166880.779	168180.183	793349.943	1263	948	
28	1263	951	. 5	5	0	0	-0.0023496	0.00020664	3.7016E-05	166880.779	168180.183	793349.943	1263	951	
29	1267	951	. 5	5	0	0	-0.0023496	0.00020664	3.7016E-05	148557.002	168180.324	938799.534	1267	951	
30	1267	952	6	6	0	0	-0.0021556	0.00024237	3.4361E-05	148557.002	168180.324	938799.534	1267	952	
31	1273	952	6	6	0	0	-0.0021556	0.00024237	3.4361E-05	116768.881	168180.834	1076486.13	1273	952	
32	1273	957	7	7	0	0	-0.0019623	0.00027525	3.1317E-05	116768.881	168180.834	1076486.13	1273	957	
33	1276	957	7	7	0	0	-0.0019623	0.00027525	3.1317E-05	73572.5221	168181.283	1207551.74	1276	957	
34	1276	958	8	8	0	0	-0.0017697	0.0003049	2.7902E-05	73572.5221	168181.283	1207551.74	1276	958	
35	1282	958	8	8	0	0	-0.0017697	0.0003049	2.7902E-05	20687.8385	168181.658	1332968.21	1282	958	
36	1282	963	9	9	0	0	-0.0015774	0.00033095	2.4132E-05	20687.8385	168181.658	1332968.21	1282	963	
37	1288	963	9	9	0	0	-0.0015774	0.00033095	2.4132E-05	-40443.462	168181.98	1453562.43	1288	963	
38	1288	964	10	10	0	0	-0.0013854	0.00035307	2.0022E-05	-40443.462	168181.98	1453562.43	1288	964	
39	1293	964	10	10	0	0	-0.0013854	0.00035307	2.0022E-05	-108609.44	168182.254	1570037.51	1293	964	
40	1293	969	11	11	0	0	-0.0011934	0.00037091	1.5581E-05	-108609.44	168182.254	1570037.51	1293	969	
41	1296	969	11	11	0	0	-0.0011934	0.00037091	1.5581E-05	-182787.32	235743.094	1682990.89	1296	969	
42	1296	972	12	12	0	0	-0.0010014	0.00038416	1.3401E-05	-182787.32	235743.094	1682990.89	1296	972	×

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/mm<sup>2</sup>. 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 <sup>2</sup>
Track 2:	57.59 N/mm <sup>2</sup>

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 <sup>2</sup>
Track 2:	103.66 N/mm <sup>2</sup>



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  $(2^{nd} \text{ pier from left abutment})$  the axial stress in the rail over the end of the first deck is equal to a tensile stress of 23.63 N/mm<sup>2</sup> while the axial stress over the start of the second deck is equal to a tensile stress of 22.47 N/mm<sup>2</sup>. 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 <sup>2</sup>
Track 2:	100.61 N/mm <sup>2</sup>

**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):	<b>46.06</b> N/mm <sup>2</sup>
Track 1 (Thermal and Train):	79.06 N/mm <sup>2</sup>
Track 2 (Thermal and Train):	92.60 N/mm <sup>2</sup>



#### 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 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/mm<sup>2</sup>.



#### 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



Figure 102: Track/Rail 1 Yield Due To Braking Train Load On Track 1 - LUSAS Combined Analysis

#### 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:

- □ 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/mm<sup>2</sup> which compares well with the code of practice value of 156.67 N/mm<sup>2</sup>.



#### 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  $\text{N/mm}^2$ .



#### 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  $N/mm^2$  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 <sup>2</sup>	
Thermal & Rail:193.06 N/mm <sup>2</sup>		

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/mm<sup>2</sup>.



#### 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/mm<sup>2</sup> which compares very well with the code of practice value of 169.14 N/mm<sup>2</sup>.



#### 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/mm<sup>2</sup>.


#### 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/mm<sup>2</sup> compressive rail stress from the simplified and the 188.23 N/mm<sup>2</sup> 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 <sup>2</sup>	
Thermal & Ra	il:195.91 N/mm <sup>2</sup>	

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/mm<sup>2</sup>.



#### 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

ISAS 19.0-Dev - F:\RailtrackVerification\H1-3\Separate\UIC H1-3 Separate Thermal Only.mdl	April 04, 3
cale: 1: 265 293 com: 100.0 onlinear analysis nalysis: Analysis 1 adcase: 1: Deck and Rail Temp (Manual NL), 1:Increment 1 esuls 1fb: ULC_HT_3_Separate_Thermal_Only-Analysis 1.mys	
eak/value entity: Force/Moment - 3D Joint (JNT4,JL43) aek/value component Fx (Units: N) aek/range(%): 100.0 aek/value maximum 20.0E3 at Gauss point 1 of element 879 aek/value maximum -20.0E3 at Gauss point 1 of element 765	
7 20 0005 20 005 20	9.474c3 8.961E3 8.475E3

# 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/mm<sup>2</sup>) 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 Braki	ing Loading 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.

	A1 • 🕞 🛵 Loading										
	A	В	С	D	E	F	G	Н		J	
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3			Amount								
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6											
7											
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9											
10											
11				Train Lo	ading Group:	1					
12											
10		Number of Track									Number
13		Loading Locations	6								Loading I
			T	Parametric	Parametric	A		Starting	Finishing	Location	
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14			De Loadeu	Loadings	Loadings	lengtinj		Analyeie	LdSL Analycic	Analysis	
15		Vertical SW/D (Left UDL)	1	-17.65	-2.65	133	15	82.35	237.65	38 825	Vertical S
16		Braking SW/D (Left UDL)	1	-17.65	-2.65	20	15	82.35	237.65	38.825	Braking
17		Vertical SW/0 (Right UD	1	2.65	17.65	133	15	82.35	237.65	38.825	Vertical §
18		Braking SW/0 (Right UD	1	2.65	17.65	20	15	82.35	237.65	38.825	Braking {
19											
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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 = 250kN/0.01m = 25000kN/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 1	Fool 🛛 🗙
Please enter the file name for the generated train loading (with *.prn 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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	MAton 2
1	This TAR delimited file defines the HSIM_A1 train definitions for a braking train travelling in the
-	positive (to the right) direction in the RTA model
2	and an accelerating train travelling in the negative (to the left) direction in the RTA model.
3	
4	The vertical and braking loads for the braking train are defined first, followed by the vertical and
-	traction loads for the accelerating train.
5	and pasted into the input spreadshet.
6	
7	Contact length for point/axle loads = 0.01
8	Origin for loading is the middle of the trainset.
9	
11	
12	BRAKING HSLM-A1 TRAIN
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14	Vertical (Left power car axle 2) TrackID -195.7675 -195.7575 17000
15	Vertical (Left power car axle 3) TrackID -184.7675 -184.7575 17000
16	Vertical (Left power car axle 4) TrackID -181.7675 -181.7575 17000
18	Vertical (Left end coach axle 1) TrackID =176.2425 = 176.2325 17000
19	Vertical (Left end coach axle 3) TrackID -163.005 -162.995 17000
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File         Ge           File         Ed           File         File           File         File     <	Whi/Geofi/Hanuals/English/Examples/RIAExample2/HiSLH-A1.pm - Notepad++       Image: Setting: Marco Run Plugns Window ?         It search View Encoding Language Setting: Marco Run Plugns Window ?       X         Image: Setting: Run Plugns Window ?       Image: Setting: Run Plugns Window ?         Vertical (Ligt: coach 18 axle 1) TrackID 144.995 145.005 17000       Image: Setting: Run Plugns Window ?         Vertical (Ligt: coach 18 axle 2) TrackID 160.995 161.005 17000       Vertical (Right end coach axle 2) TrackID 162.995 163.005 17000         Vertical (Right end coach axle 2) TrackID 176.225 176.2425 17000       Vertical (Right power car axle 2) TrackID 178.2325 176.2425 17000         Vertical (Right power car axle 1) TrackID 181.7575 181.7675 17000       Vertical (Right power car axle 2) TrackID 185.7575 198.7675 17000         Vertical (Right power car axle 3) TrackID 195.7575 198.7675 17000       Vertical (Right power car axle 4) TrackID 198.7575 198.7675 17000         Vertical (Right power car axle 3) TrackID 198.7575 198.7675 17000       Vertical (Right power car axle 4) TrackID 198.7575 198.7675 17000         Vertical (Lift power car axle 3) TrackID -198.7675 -198.7575 17000       Vertical (Lift power car axle 3) TrackID -198.7675 -195.7575 17000         Vertical (Lift power car axle 4) TrackID -198.7675 -195.7575 17000       Vertical (Lift power car axle 4) TrackID -198.7675 -195.7575 17000         Vertical (Lift power car axle 4) TrackID -18.7425 -176.2325 17000       Vertical (Lift end coach axle 3) TrackID -18.7425 -178.2325 17000         Vertical (Lift end
Image: Second	Whi/Geofi/Hanuals/English/Examples/RTAExample2/Wi5LH-ALprn - Notepad++       Image: Settings: Maco: Run Plugns: Window ?         It seeth Vew Encoding Language Settings: Maco: Run Plugns: Window ?       X         MAIp: Image: Settings: Maco: Run Plugns: Window ?       X         Wertical (Ing.: coach 18 axle 1) TrackID 144.995 145.005 17000       Image: Run Plugns: Window ?         Vertical (Ing.: coach 18 axle 2) TrackID 162.995 163.005 17000       Vertical (Right end coach axle 2) TrackID 176.2325 176.2425 17000         Vertical (Right end coach axle 1) TrackID 176.2325 176.2425 17000       Vertical (Right power car axle 2) TrackID 181.7575 181.7675 17000         Vertical (Right power car axle 1) TrackID 198.7575 198.7675 17000       Vertical (Right power car axle 4) TrackID 198.7575 198.7675 17000         Vertical (Right power car axle 4) TrackID 198.7575 198.7675 17000       Vertical (Right power car axle 4) TrackID 198.7575 198.7675 17000         Vertical (Right power car axle 4) TrackID 198.7575 198.7675 17000       Vertical (Right power car axle 4) TrackID 198.7575 198.7675 17000         Vertical (Left power car axle 4) TrackID -198.7675 -198.7575 17000       Vertical (Left power car axle 4) TrackID 198.7575 17000         Vertical (Left power car axle 1) TrackID -198.7675 -198.7575 17000       Vertical (Left power car axle 4) TrackID -198.7575 17000         Vertical (Left power car axle 3) TrackID -198.7575 -190.7575 17000       Vertical (Left power car axle 4) TrackID -198.7575 -190.7575 17000         Vertical (Left power car axle 3) TrackID -198.7675 -198.7575

Figure 139: Output for a HSLM-A1 Trainset Configuration (1 of 2)

🔡 E:\S\	VII\Geoff\Manuals\Manuals\Examples\RTAExample2\H5LM-A1.pm - Notepad++
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HSLI	M-A1pm 12
99	Vertical (Int. coach 11 axle 2) TrackID 34.995 35.005 17000
100	Vertical (Int. coach 12 axle 1) TrackID 36.995 37.005 17000
101	Vertical (Int. coach 12 axle 2) TrackID 52.995 53.005 17000
102	Vertical (Int. coach 13 axle 1) TrackID 54.995 55.005 17000
103	Vertical (Int. coach 13 axle 2) TrackID 70.995 71.005 17000
104	Vertical (Int. coach 14 axle 1) TrackID 72.995 73.005 17000
105	Vertical (Int. coach 14 axle 2) TrackID 88.995 89.005 17000
106	Vertical (Int. coach is axie i) Trackib 90.995 91.005 17000
107	Vertical (Int. coach is axie 2) Trackib 106.995 107.005 17000
108	Vertical (Int. coach 16 axie 1) frackib 108.995 109.005 1/000
110	Vertical (Int. coach 16 axie 2) Ifachib 124.995 125.005 1/000
111	Vertical (Jut. Coach 1/ avia 2) TrackID 120,553 12/1003 1/000
112	Vertical (Int. coach 18 avie 1) Tracking 144 995 145.005 17000
113	Vertical (Int. coach 18 avle 2) TrackD 160 995 161 005 17000
114	Vertical (Right end coach axle 1) TrackTD 162.995 163.005 17000
115	Vertical (Right end coach axle 2) TrackID 176.2325 176.2425 17000
116	Vertical (Right end coach axle 3) TrackID 178.2325 178.2425 17000
117	Vertical (Right power car axle 1) TrackID 181.7575 181.7675 17000
118	Vertical (Right power car axle 2) TrackID 184.7575 184.7675 17000
119	Vertical (Right power car axle 3) TrackID 195.7575 195.7675 17000
120	Vertical (Right power car axle 4) TrackID 198.7575 198.7675 17000
121	Traction (Left power car) TrackID -198.7625 -181.7625 29.4117647058824
122	Traction (Right power car) TrackID 181.7625 198.7625 29.4117647058824
123	
124	Traction load UDL has been factored as total load over the two 17 m power cars is 1122 kN (> 1000 kN limit
	for default UDL)
125	Traction load UDL reduced to = 29.4117647058824 $kN/m$
126	
Normal te	ext 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

	A13 🗸 🕤 J	🕼 Vertic	al (Left pov	ver car axle	1)								3
	A	В	С	D	E	F	G	н	1	J	K	L	
1	This TAB delimited file defines th	ne HSLM-A	≏1 train def	initions for	a braking trai	n travellin	g in the po	sitive (to f	the right) o	irection in	the RTA m	odel	
2	and an accelerating train travellir	ng in the r	negative (to	the left) d	irection in the	RTA mod	el.						
3	Ŭ		Ŭ,	,									
4	The vertical and braking loads for	r the braki	ing train are	e defined fi	rst. followed b	ov the ver	tical and tr	action loa	ds for the a	ocelerating	ztrain.		
5	After importing into Microsoft Ex	cel the ap	opropriate l	oads for th	e analysis beir	, ng conside	red can be	copied ar	nd pasted i	nto the inp	ut spreads	heet.	
6													
7	Contact length for point/axle loa	ds = 0.01											
8	Origin for loading is the middle o	of the train	nset.										
9	0												
10													
11													
12	REAKING HSLM-A1 TRAIN												
12	Vertical (Left power car avie 1)	TrackID	.100 7675	.100 7575	17000								
1.0	Vertical (Left power car axie 1)	TrackID	105 7675	105 7575	17000								
14	Vertical (Left power car axie 2)	TrackID	-195.7675	-190,7070	17000								
15	Vertical (Left power car axie 5)	TrackID	-104.7675	-104.7373	17000								
16	Vertical (Left power car axie 4)	TrackID	-181.7675	-181. /5 /5	17000								-
17	Vertical (Left end coach axie 1)	TrackID	-178.2425	-178.2325	17000								
18	Vertical (Left end coach axie 2)	TrackID	-1/6.2425	-176.2325	17000								-
19	Vertical (Left end coach axie 3)	TrackID	-163.005	-162.995	17000								-
20	vertical (int. coach 1 axie 1)	TrackID	-161.005	-160.995	1/000								+
21	vertical (int. coach 1 axle 2)	TrackID	-145.005	-144.995	17000								+
22	vertical (Int. coach 2 axle 1)	TrackID	-143.005	-142.995	17000								+
23	Vertical (Int. coach 2 axle 2)	TrackID	-127.005	-126.995	17000								
24	Vertical (Int. coach 3 axle 1)	TrackID	-125.005	-124.995	17000								
25	Vertical (Int. coach 3 axle 2)	TrackID	-109.005	-108.995	17000								
26	Vertical (Int. coach 4 axle 1)	TrackID	-107.005	-106.995	17000								
27	Vertical (Int. coach 4 axle 2)	TrackID	-91.005	-90.995	17000								
28	Vertical (Int. coach 5 axle 1)	TrackID	-89.005	-88.995	17000								
29	Vertical (Int. coach 5 axle 2)	TrackID	-73.005	-72.995	17000								
30	Vertical (Int. coach 6 axle 1)	TrackID	-71.005	-70.995	17000								
31	∨ertical (Int. coach 6 axle 2)	TrackID	-55.005	-54.995	17000								
32	Vertical (Int. coach 7 axle 1)	TrackID	-53.005	-52.995	17000								
33	Vertical (Int. coach 7 axle 2)	TrackID	-37.005	-36.995	17000								
34	Vertical (Int. coach 8 axle 1)	TrackID	-35.005	-34.995	17000								
35	Vertical (Int. coach 8 axle 2)	TrackID	-19.005	-18.995	17000								
36	Vertical (Int. coach 9 axle 1)	TrackID	-17.005	-16.995	17000								
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37 38 39 40 41 42	A13   A13  A Vertical (Int. coach 9 axle 2) Vertical (Int. coach 10 axle 1) Vertical (Int. coach 10 axle 2) Vertical (Int. coach 11 axle 2) Vertical (Int. coach 11 axle 2) Vertical (Int. coach 11 axle 2)	Vertic B TrackID TrackID TrackID TrackID TrackID TrackID	c -1.005 0.995 16.995 18.995 34.995 36.995	ver car axle D -0.995 1.005 17.005 19.005 35.005 37.005	17000 17000 17000 17000 17000 17000 17000	F	G	Н	1	J	К	L	
37 38 39 40 41 42 43	A13   Vertical (Int. coach 9 axle 2) Vertical (Int. coach 9 axle 2) Vertical (Int. coach 10 axle 1) Vertical (Int. coach 11 axle 1) Vertical (Int. coach 11 axle 2) Vertical (Int. coach 11 axle 2) Vertical (Int. coach 12 axle 1) Vertical (Int. coach 12 axle 1)	Vertic B TrackID TrackID TrackID TrackID TrackID TrackID TrackID	c (Left pov -1.005 0.995 16.995 18.995 34.995 36.995 52.995	ver car axle D -0.995 1.005 17.005 19.005 35.005 37.005 53.005	17000 17000 17000 17000 17000 17000 17000 17000	F	G	Н	1	مر است ۲	К	L	
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37           38           39           40           41           42           43           44           45           46           47           48           49           50           51           52           53           54           55           56           577           58           59           60           61           62           63           64	A13  Vertical (Int. coach 9 avle 2) Vertical (Int. coach 10 avle 1) Vertical (Int. coach 10 avle 2) Vertical (Int. coach 11 avle 1) Vertical (Int. coach 11 avle 1) Vertical (Int. coach 11 avle 1) Vertical (Int. coach 12 avle 2) Vertical (Int. coach 12 avle 2) Vertical (Int. coach 13 avle 2) Vertical (Int. coach 13 avle 2) Vertical (Int. coach 14 avle 2) Vertical (Int. coach 14 avle 2) Vertical (Int. coach 14 avle 2) Vertical (Int. coach 15 avle 1) Vertical (Int. coach 15 avle 1) Vertical (Int. coach 15 avle 1) Vertical (Int. coach 15 avle 2) Vertical (Int. coach 15 avle 2) Vertical (Int. coach 16 avle 2) Vertical (Int. coach 16 avle 2) Vertical (Int. coach 18 avle 2) Vertical (Int. coach 18 avle 2) Vertical (Right end coach avle 3) Vertical (Right end coach avle 3) Vertical (Right power car avle 2) Vertical (Right power car avle 2) Vertical (Right power car avle 2) Vertical (Right power car avle 3) Vertical (Right power car avle 4) Braking	Vertici      Vertici      Vertici      Vartici	Image: constraint of the system           c         -1.005           0.995         16.995           16.995         36.995           34.995         52.995           54.995         88.995           90.995         106.995           106.995         126.995           124.995         142.995           144.995         144.995           176.2325         178.2325           181.7575         198.7575           198.7575         198.7575           -198.7625         -198.7625	D 0 0 0 0 0 0 0 0 0 0 0 0 0	1) E 1000 1700	F	G	H			K		
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<ul> <li>337</li> <li>38</li> <li>39</li> <li>40</li> <li>41</li> <li>42</li> <li>43</li> <li>44</li> <li>45</li> <li>46</li> <li>47</li> <li>48</li> <li>49</li> <li>50</li> <li>51</li> <li>52</li> <li>53</li> <li>54</li> <li>55</li> <li>56</li> <li>57</li> <li>58</li> <li>59</li> <li>60</li> <li>61</li> <li>62</li> <li>63</li> <li>64</li> <li>65</li> <li>66</li> <li>67</li> <li>68</li> </ul>	A13  Vertical (Int. coach 9 avie 2) Vertical (Int. coach 10 avie 2) Vertical (Int. coach 10 avie 2) Vertical (Int. coach 11 avie 1) Vertical (Int. coach 11 avie 1) Vertical (Int. coach 12 avie 1) Vertical (Int. coach 12 avie 1) Vertical (Int. coach 13 avie 2) Vertical (Int. coach 13 avie 2) Vertical (Int. coach 13 avie 1) Vertical (Int. coach 13 avie 2) Vertical (Int. coach 13 avie 2) Vertical (Int. coach 14 avie 2) Vertical (Int. coach 15 avie 2) Vertical (Int. coach 16 avie 1) Vertical (Int. coach 18 avie 2) Vertical (Int. coach 18 avie 2) Vertical (Right end coach avie 3) Vertical (Right end coach avie 3) Vertical (Right end coach avie 3) Vertical (Right power car avie 4) Braking Braking load UDL has been factor Braking load UDL reduced to = 15	Verticit     Verticitt     Verticitt     Verticitt	Id (Left pov           C           -1.005           0.995           16.995           34.995           36.995           52.995           54.995           70.995           90.995           106.995           108.995           108.995           124.995           124.995           126.995           142.995           160.295           176.2325           177.2325           181.7575           198.7575           198.7575           198.7525           I load over           2808 kN/m	D 0 -0.935 1.005 35.005 53.005 53.005 53.005 53.005 91.005 53.005 91.005 107.005 91.005 107.005 1007.005 1007.	1) E 1) E 17000 17	77950.5 KN	G G (> 5000 kN	H	III III IIIIIIIIIIIIIIIIIIIIIIIIIIIIII		K		
<ul> <li>37</li> <li>38</li> <li>39</li> <li>40</li> <li>41</li> <li>42</li> <li>43</li> <li>44</li> <li>45</li> <li>46</li> <li>47</li> <li>48</li> <li>49</li> <li>50</li> <li>51</li> <li>52</li> <li>53</li> <li>54</li> <li>55</li> <li>56</li> <li>56</li> <li>66</li> <li>67</li> <li>68</li> <li>69</li> </ul>	A13  Vertical (Int. coach 9 avle 2) Vertical (Int. coach 10 avle 1) Vertical (Int. coach 10 avle 1) Vertical (Int. coach 11 avle 1) Vertical (Int. coach 11 avle 1) Vertical (Int. coach 12 avle 2) Vertical (Int. coach 12 avle 2) Vertical (Int. coach 13 avle 2) Vertical (Int. coach 14 avle 2) Vertical (Int. coach 14 avle 2) Vertical (Int. coach 15 avle 1) Vertical (Int. coach 17 avle 2) Vertical (Int. coach 17 avle 2) Vertical (Int. coach 17 avle 1) Vertical (Right end coach avle 3) Vertical (Right power car avle 2) Vertical (Right power car avle 3) Partial (Right power car avle 3) Partial (Right power car avle 4) Braking Braking Load UDL has been factor Braking Load UDL reduced to = 15	Vertic     Vertic     Vertic     Vertic     Vartick     Varti	Id (Left pov           C           -1.005           0.995           16.995           34.995           34.995           36.995           70.995           70.995           71.995           90.995           106.995           124.995           124.995           126.995           160.995           176.2325           176.2325           198.7575           198.7575           198.7575           198.7575           198.7525           I load over           2808 kN/m	D 0 0 0 0 0 0 0 0 0 0 0 0 0	1) E 1) E 17000 17	F 7950.5 kN	G G (> 6000 kN	H	III UTATE		K		
- 37 37 38 38 39 40 41 42 42 44 45 46 47 48 49 50 51 52 53 55 55 55 55 55 56 57 55 56 57 58 9 60 61 62 63 64 65 66 66 67 68 69 70 70	A13	Vertici     Vertici     Vertici     Vertici     Vertici     Vartacki     Vartacki     Vartacki     Varacki     Varacki     Tracki     Oracki     Orac	C C C C C C C C C C C C C C C C C C C	Ver car aule D -0.935 1.005 53.005 53.005 53.005 53.005 73.005 91	1) E 10 E 1700 170	F F 77950.5 kN	G G (> 6000 kN	H	I I I I I I I I I I I I I I I I I I I		K		
-           37           38           39           40           41           42           43           44           45           46           47           48           49           50           51           52           53           56           57           58           59           60           61           62           63           64           65           66           67           68           69           70           71	A13  Vertical (Int. coach 9 avie 2) Vertical (Int. coach 10 avie 2) Vertical (Int. coach 11 avie 1) Vertical (Int. coach 11 avie 1) Vertical (Int. coach 11 avie 1) Vertical (Int. coach 12 avie 2) Vertical (Int. coach 12 avie 2) Vertical (Int. coach 13 avie 2) Vertical (Int. coach 14 avie 2) Vertical (Int. coach 14 avie 2) Vertical (Int. coach 15 avie 1) Vertical (Int. coach 15 avie 2) Vertical (Int. coach 15 avie 1) Vertical (Int. coach 15 avie 2) Vertical (Int. coach 15 avie 2) Vertical (Int. coach 15 avie 2) Vertical (Int. coach 16 avie 1) Vertical (Int. coach 16 avie 2) Vertical (Int. coach 16 avie 2) Vertical (Right end coach avie 3) Vertical (Right end coach avie 3) Vertical (Right power car avie 4) Vertical (Right power car avie 4) Parking load UDL has been factor Braking load UDL reduced to = 15 ACCELERATING HSLM-A1 TRAIN Vertical (Left power car avie 4)	Vertic     Vertic     Vertic     Vertic     Vartic	La (Left pov - 1.005 0.995 16.995 34.995 54.995 70.995 70.995 88.995 106.995 106.995 124.995 124.995 144.995 144.995 176.2355 176.2355 178.2325 198.7575 198.7575 198.7575 198.7575 198.7675	ver ca a solution of the second secon	1) E 1) E 1) C 17000 17	F 7750.5 kN	G G (> 5000 km	H	IL DIRE		K		
- 37 38 39 40 41 43 44 45 50 51 52 53 54 55 55 55 55 55 55 55 55 56 60 61 62 63 64 65 66 67 70 71 77 77 77	A13	Vertici     Vertici     Vertici     Vertici     Vartici     Vartici     Vartici     VartakiD     TrackiD	C C C C C C C C C C C C C C C C C C C	ver car avide D -0.935 1.005 13.005 53.005 53.005 53.005 71.00	1) E 1) E 17000 17	F 7950.5 kN	G (> 5000 kN	H	IL UTION OF A CONTRACT OF A CO		K		
- 37 38 39 40 41 42 43 44 45 47 48 49 50 51 52 53 54 55 55 56 57 58 59 50 60 61 62 63 64 65 66 67 70 71 72 2 70 70 70 70 70 70 70 70 70 70	A13	Vertic	al (Left pov C -1.005 0.995 16.995 34.995 34.995 52.995 52.995 54.995 72.995 90.995 106.995 124.995 124.995 124.995 124.995 126.995 126.995 126.995 126.995 137.225 138.7575 198.7575 198.7575 198.7675 -198.7675	Ver car ade D 0 -0.935 1.005 17.005 53.005 53.005 53.005 53.005 53.005 107.005 91.005 107.005 91.005 127.005 127.005 127.005 127.005 127.005 128.005 127.005 128.005 178.225 198.7675 198.7575 -1.98	1) E 1000 17000 15.09393935	F 7950.5 kN	G (> 6000 kN	H	III III IIIIIIIIIIIIIIIIIIIIIIIIIIIIII		K		

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.

	B15 • 🖉 Vertical (Left power car axle 1)											
	A	В	С	D	E	F	G	Н	1	J	-	
1	Loading Units : Temperature : Celsius , Load			osition/Leng	th:m,Load						E	
2												
3												
4	Temperature Loads	Deck										
5	Rails											
6												
7		Ì										
8		Num	ber of Train L	bading Group	s to Analyse							
9				-								
10						ĺ						
11				Train Lo	ading Group:	1						
12												
		Number of Track									Numb	
13		Loading Locations									Loadin	
		Loading Type	Track Selection to	Parametric Starting Position for	Parametric End Position for	Amount (per unit	Loaded Length	Starting Location of Loading for	Location of Locating for	Location Increment for each	L	
14			De Loaded	Loadings	Loadings	length)		Analysis	Analysis	Analysis		
15		Vertical (Left power car	TrackID	-198.7675	-198.7575	17000	0.01					
16		Vertical (Left power car	TrackID	-195.7675	-195.7575	17000	0.01					
17		Vertical (Left power car a	TrackID	-184.7675	-184.7575	17000	0.01					
18		Vertical (Left power car	TrackID	-181.7675	-181.7575	17000	0.01					
19		Vertical (Left end coach	TrackID	-1/8.2425	-1/8.2325	1/000	0.01					
20	Train Loads	Vertical (Left end coach	TrackID	-1/6.2425	-1/6.2325	17000	0.01					
21		Vertical (Leit end coach 1 av	TrackID	-163.005	-160.995	17000	0.01				• •••••	
23		Vertical (Int. coach 1 ax	TrackID	-101.005	-100.995	17000	0.01					
24		Vertical (Int. coach 2 ax	TrackID	-143,005	-142,995	17000	0.01					
25		Vertical (Int. coach 2 ax	TrackID	-127.005	-126.995	17000	0.01					
00		Vertical (Int. coach 3 ax	TrackID	-125.005	-124.995	17000	0.01			,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		
26					100.005	47000	0.04					
26		Vertical (Int. coach 3 ax	TrackID	-109.005	-108.995	17000	0.01					
26 27 28		Vertical (Int. coach 3 ax Vertical (Int. coach 4 ax	TrackID TrackID	-109.005 -107.005	-108.995 -106.995	17000	0.01					

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
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       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
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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
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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
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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"
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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("")
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```
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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