

The logo features six 3D-rendered spheres arranged in a circular pattern around the central text. The spheres are colored green, purple, orange, grey, pink, and blue.

# LUSAS

*Engineering analysis and design software*



*Software option for*



**LUSAS**

*Bridge*

# LUSAS Rail Track-Structure Interaction Analysis

Account Manager Name

Job Title, LUSAS

# Introduction

- Growth in High Speed & Light Rail infrastructure
- Requirement for:
  - Accurate modelling of track-structure interaction
  - Prediction of stresses in rails and behaviour of the track-structure system under the action of thermal and trainset loading
  - Consideration of multiple trainset configurations to take account of both braking and accelerating trainsets
- Hand calculation methods are available but computer analysis methods:
  - Speed up the investigation / prediction process
  - Allow optimisation of the design

# LUSAS Tools

- LUSAS Rail Track Analysis provides:
  - Analysis to the UIC 774-3 Code of Practice
  - Automatic model building from MS Excel spreadsheets
  - Multiple analyses of multiple trainsets
  - Results in spreadsheet or LUSAS formats
- This saves time
  - Is less error prone
  - Allows for multiple analysis and optimisation of design

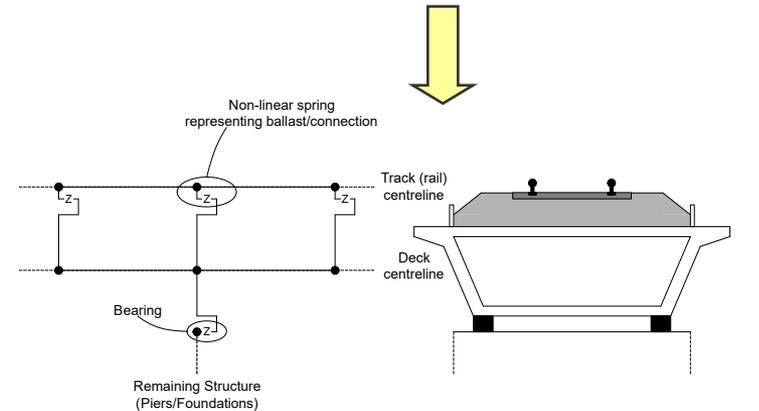
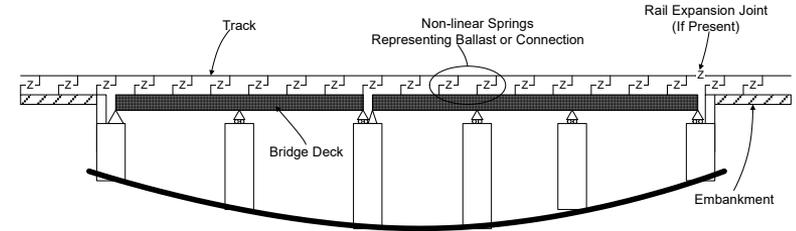


# UIC774-3 Code of Practice

- Requires analysis / assessment of track-structure interaction effects including:
  - Longitudinal reactions at supports
  - Rail stresses induced by temperature and train loading effects
  - Absolute and relative displacements of the rails and deck (for ballasted or ballastless track)

# Analysis Required to Satisfy UIC774-3

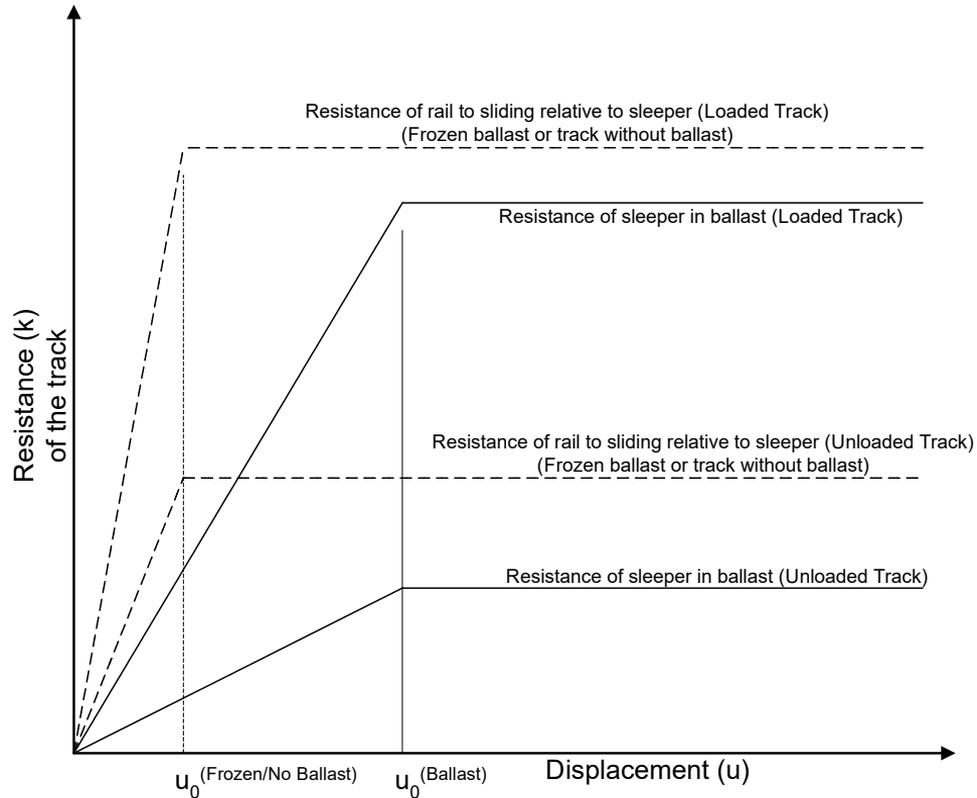
- Nonlinear analysis is needed to investigate:
  - Thermal loading on the bridge deck
  - Thermal loading on the rail if any rail expansion devices are fitted
  - Vertical loads associated with the trainsets
  - Longitudinal braking and/or acceleration loads associated with the trainsets



Longitudinal Schematic Of The Model

Transverse Cross-Section Of Track-Deck-Bearing System

# Track and Bridge Interaction



# Modelling to UIC774-3

- No requirement in UIC774-3 to consider a detailed model of the substructure for standard bridges
  - Instead substructure can be modelled using constraints and/or spring supports
- LUSAS Rail Track Analysis
  - Can model according to UIC774-3
  - But also allows explicit modelling of bearing-pier/abutment-foundation systems where each component is defined

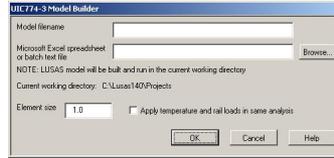
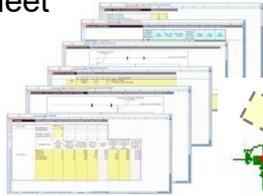
# LUSAS Rail Track Analysis

- Builds LUSAS models automatically
  - from MS Excel spreadsheet data
- Has batch capabilities to allow for multiple structures and multiple load configurations
- Automatically updates the material properties associated with the track/structure interface based upon the position of the train or trains
- Produces rail and structure results that can be written to MS Excel for presentation / additional processing

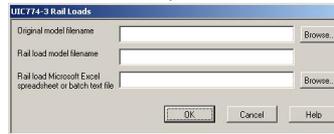
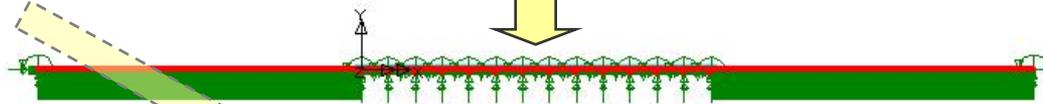


# Rail Track Analysis: Method

1. Model 'trainset' data is defined in Microsoft Excel spreadsheet



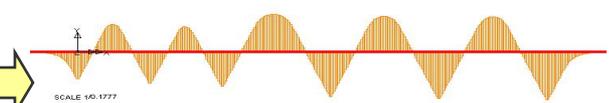
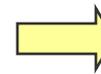
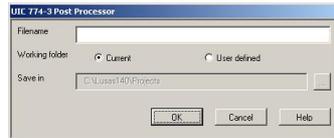
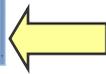
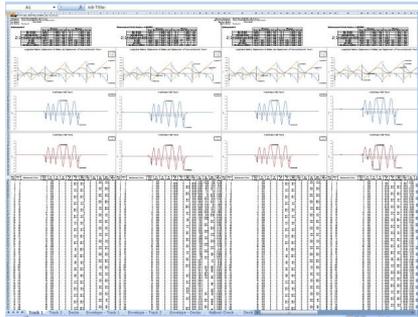
2. Rail Track Analysis option selected and modelling options specified



3. Finite element model is built automatically

4. Trainset loading is specified

5. Results options



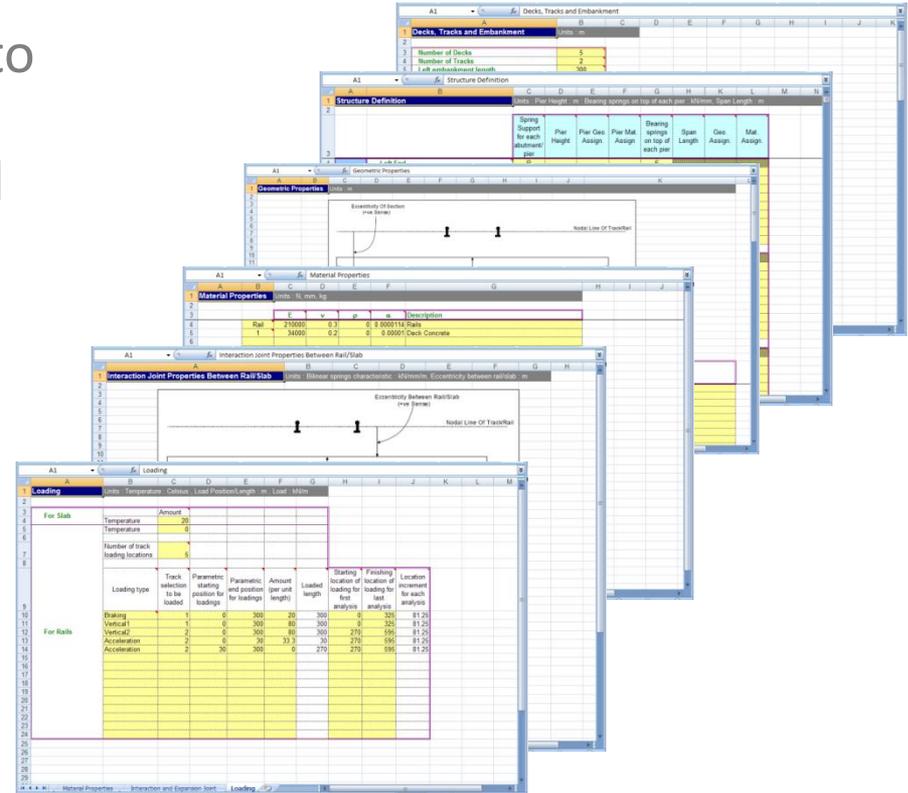
```
SCALE 1/0.1777  
EYE X=0.0000E+00 Y=0.0000E+00 Z=1000  
NONLINEAR ANALYSIS  
LOAD CASE ID = 1  
Iteration 1  
RESULTS FILE ID = 1  
TYPE STRESS  
DIAGRAM COMPONENT = FX  
MAX: 0.0599E+00 AT EL:170P 436/1  
MIN: 0.7055E+00 AT EL:170P 829/1  
DIAGRAM SCALE = 1/0.4167E-01
```

Results and automated graphing in Microsoft Excel



# Rail Track Analysis Spreadsheet

- Consists of separate worksheets to define:
  - Number of decks, tracks and embankment lengths
  - Structure Definition
  - Geometric Properties
  - Material Properties
  - Interaction and Expansion Joint Properties
  - Loading



# Worksheet 1 : General details

The screenshot shows a spreadsheet window with the following data:

	A	B	C	D	E	F	G	H	I	J
1	<b>Decks, Tracks and Embankment</b>	Units : m								
2										
3	<b>Number of Decks</b>	5								
4	<b>Number of Tracks</b>	2								
5	<b>Left Embankment Length</b>	300								
6	<b>Right Embankment Length</b>	300								
7	<b>Length of Decks Only / Total Length (m)</b>	60	660							
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

The spreadsheet window title is "Decks, Tracks and Embankment". The bottom status bar shows the following tabs: "No. Decks, Tracks and Embank Len", "Structure Definition", "Geometric Properties", "Material Properties", and "Interaction and Expansion Join".

# Worksheet 2 : Structure definition

	A	B	C	D	E	F	G	H	K	L	M
1	<b>Structure Definition</b>		Units : Pier Height : m ; Bearing springs on top of each pier : kN/mm, Span Length : m								
2			Spring Support for each Abutment /Pier	Pier Height	Pier Geo. Assign.	Pier Mat. Assign	Bearing Springs on Top of each Pier	Span Length	Geo. Assign.	Mat. Assign.	
3											
4	Deck 1	Left End	R				R				
5		Span 1	R				307	25	1	1	
6		Span 2	R				F	25	1	1	
7		Span 3									
8		Span 4									
9		Span 5									
10		Span 6									
11		Span 7									
12		Span 8									
13		Span 9									
14	Number of Supports for the Deck / Length		3				3	50			
15	Deck 2	Left End	R				F				
16		Span 1	R				307	25	1	1	
17		Span 2	R				F	25	1	1	
18		Span 3									
19		Span 4									
20		Span 5									
21		Span 6									
22		Span 7									
23		Span 8									
24		Span 9									
25	Number of Supports for the Deck / Length		3				3	50			
26	Deck 3	Left End	R				F				
27		Span 1	R				259	25	1	1	
28		Span 2	R				F	25	1	1	
29		Span 3	R				F	25	1	1	
30		Span 4									
31		Span 5									
32		Span 6									
33		Span 7									
34	Span 8										



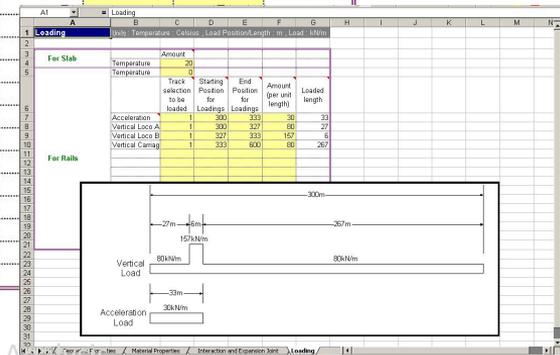
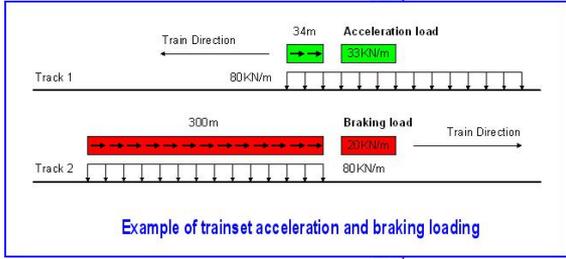
# Worksheet 4 : Material Properties

1	Material Properties	Units : N, mm, kg													
3		E	v	p	α										
4	Rail	210000	0.3	0	0.0000114										
5	1	34000	0.2	0	0.00001										
6															
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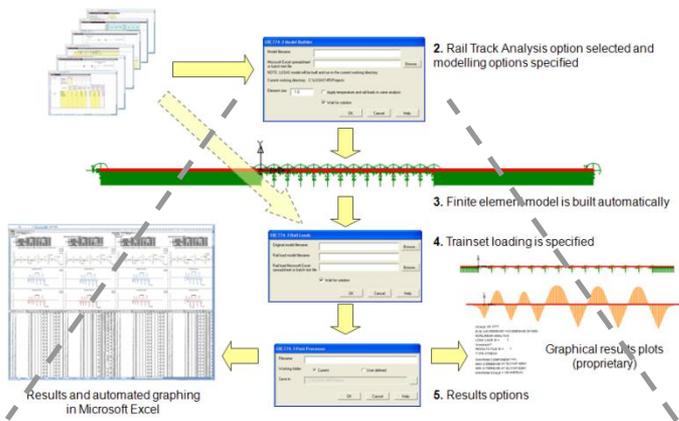


# Worksheet 6 : Thermal + Train Loading

A1		Loading									
A		B	C	D	E	F	G	H	I	J	
1	<b>Loading</b>	Units : Temperature : Celsius , Load Position/Length : m , Load : kN/m									
2											
3	<b>For Deck</b>		Amount								
4		Temperature	35								
5		Temperature	50								
		Number of Track Loading Locations	16								
		Loading Type	Track Selection to be Loaded	Parametric Starting Position for Loadings	Parametric End Position for Loadings	Amount (per unit length)	Loaded Length	Starting Location of Loading for First Analysis	Finishing Location of Loading for Last Analysis	Location Increment for each Analysis	
		Braking	1	0	300	20	300	0	150	10	
		Vertical	1	0	300	80	300	0	150	10	
11	<b>For Rails</b>										
12											
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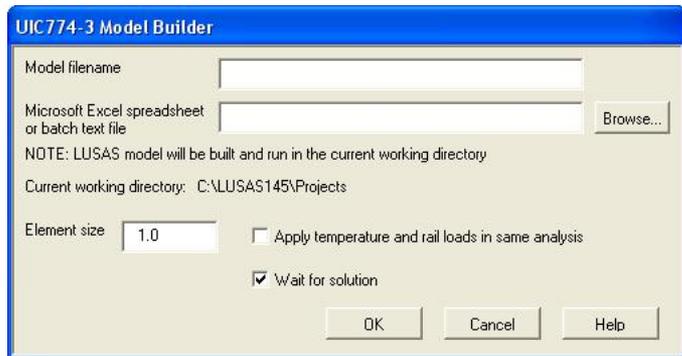


# Model Builder Dialog

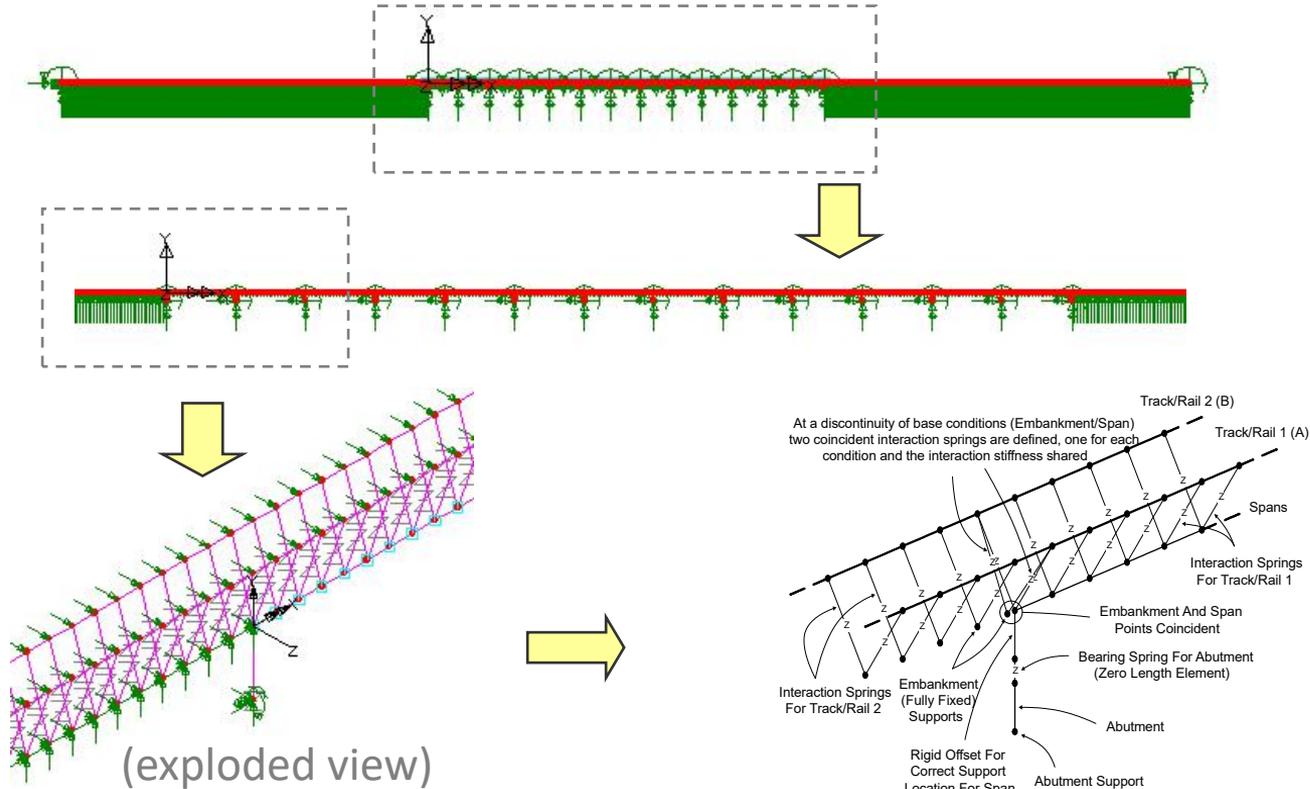


- Allows:

- Thermal only analyses
- Combined thermal and trainset loading analyses with a constant trainset configuration but varying positions
- Batch processing of multiple analyses of the same or different structures

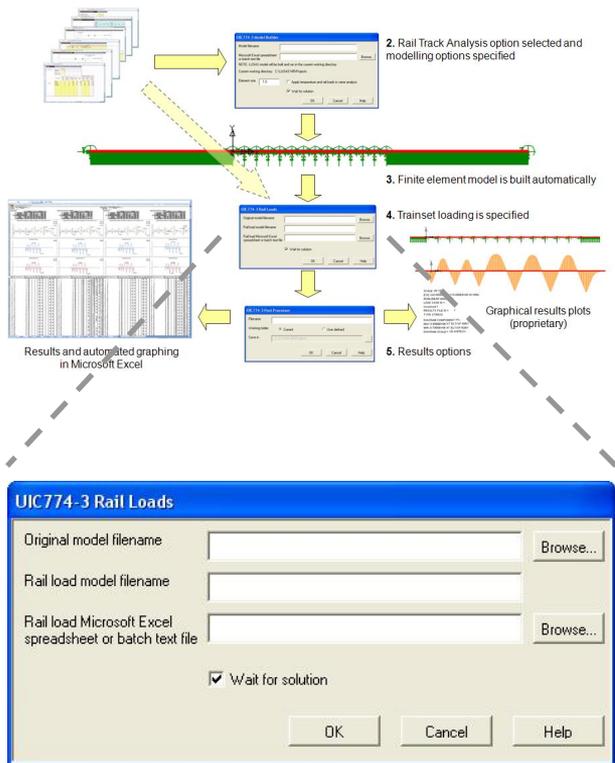


# Typical Rail Track Analysis Model



(exploded view)

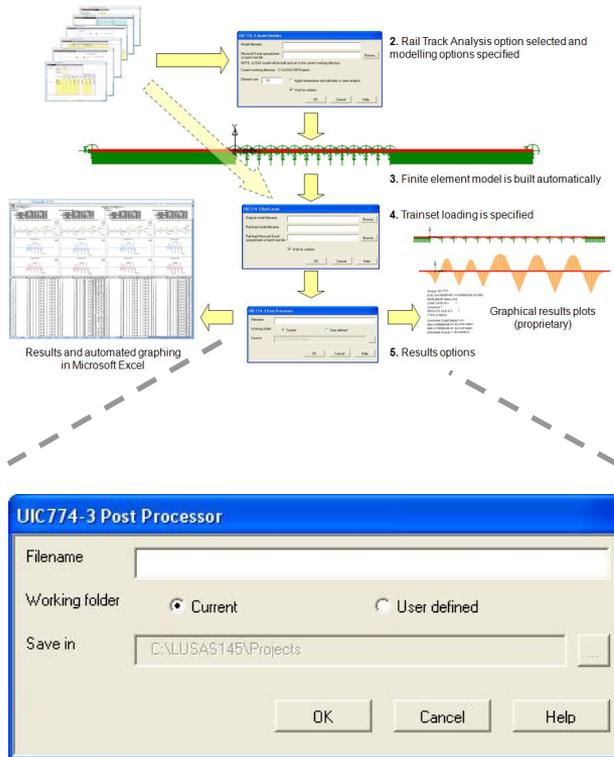
# Apply Rail Loads Dialog



- Allows:

- Application of rail loads to an existing thermal only model
- Consideration of different trainset configurations without the need to rebuild the structural model
- Batch processing of multiple analyses of the same or different structures

# Post-Processor Dialog



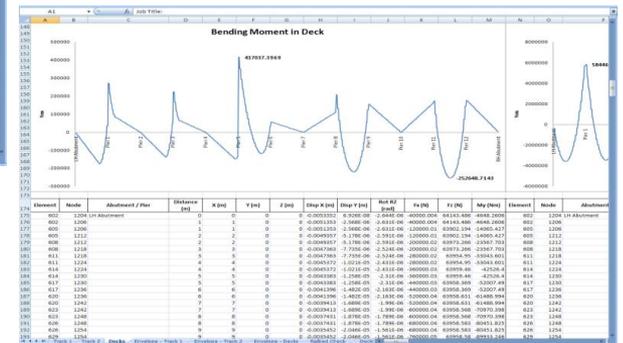
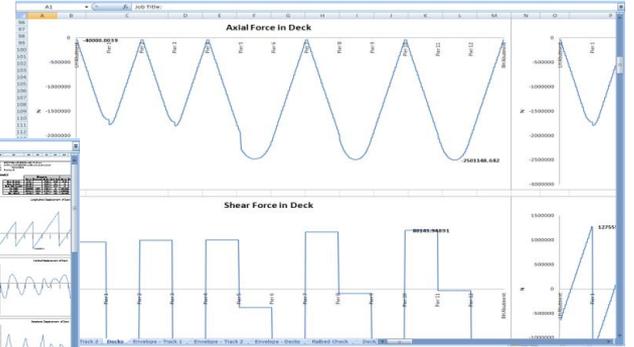
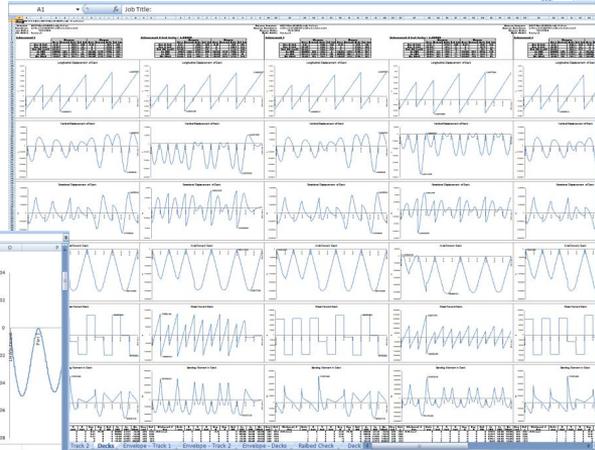
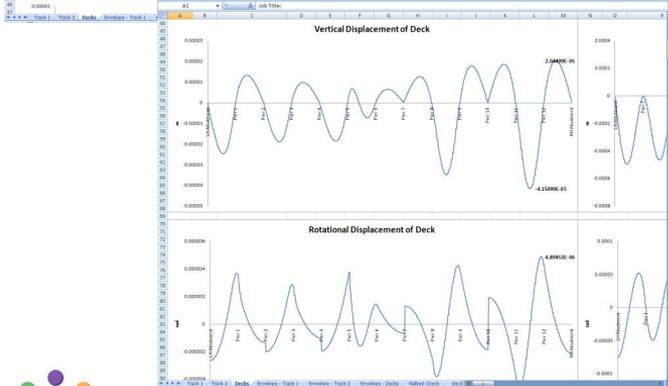
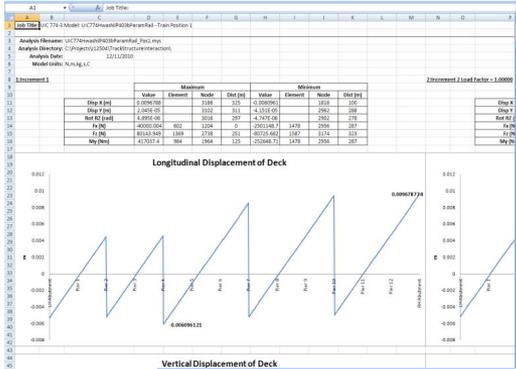
- Provides:
  - Automatic extraction & graphing of raw displacements and forces/moments results for the tracks & structure
  - Envelopes of peak behaviour & graphs
  - Summary tables of key quantities such as rail stresses, reactions and relative displacements of the track/structure & decks

# Excel Results

- Results spreadsheets contain worksheets of results for specific areas of interest:
  - Track 1, 2
  - Deck 1, 2, etc
  - Envelope, Track 1, 2
  - Envelope, Deck 1, 2 etc
  - Railbed Check
  - Longitudinal Reactions Check
  - Rail Stresses Check

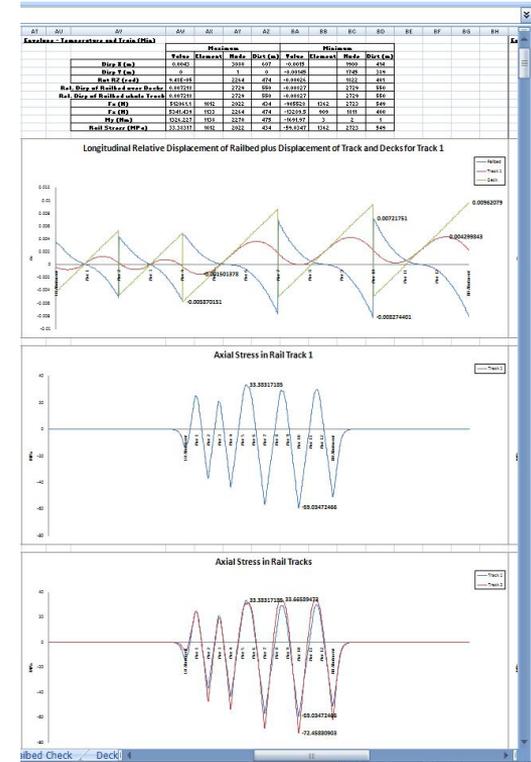


# Deck results



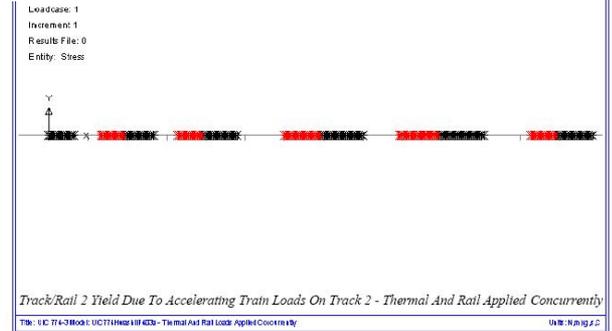
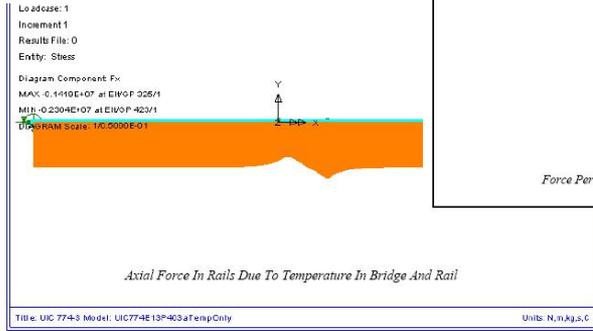
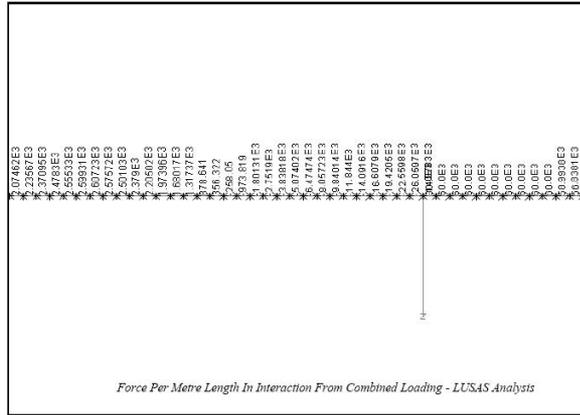
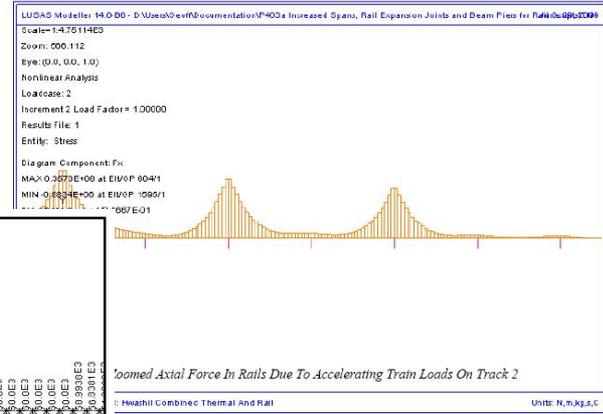
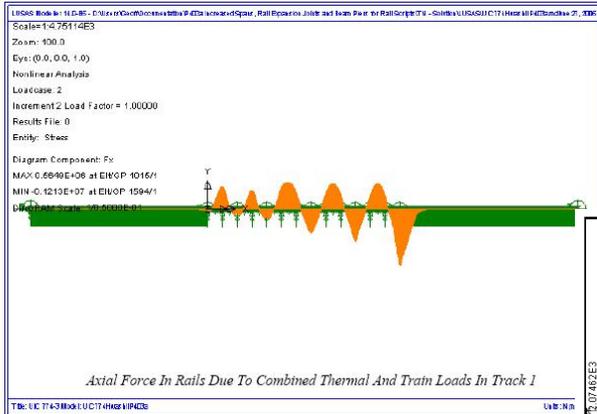
# Envelopes

- Max and min envelopes are calculated based upon raw track and deck data for:
  - Temperature loading only
  - Temperature and trainset rail loading
  - An envelope of both the above envelopes
- Output as summary, graph and tabular data

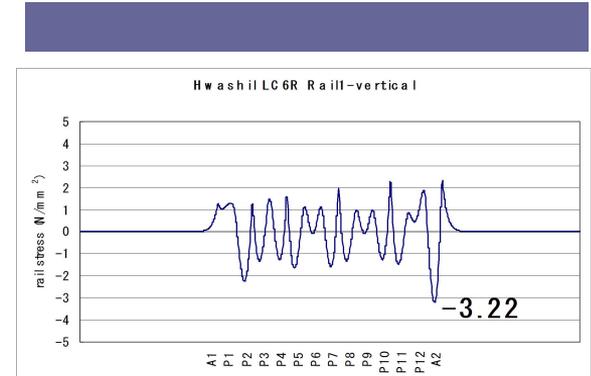
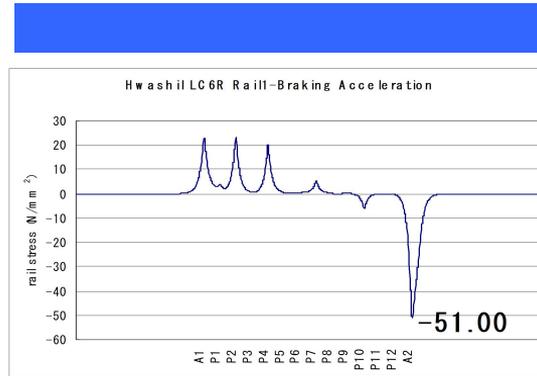
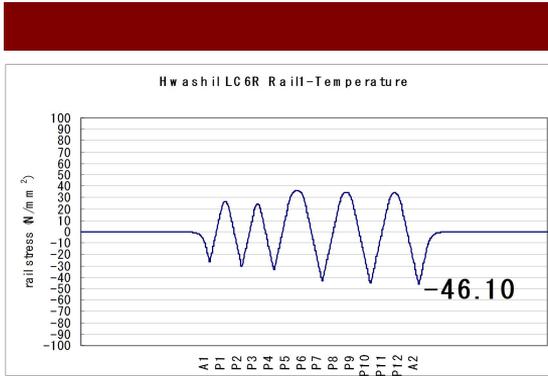




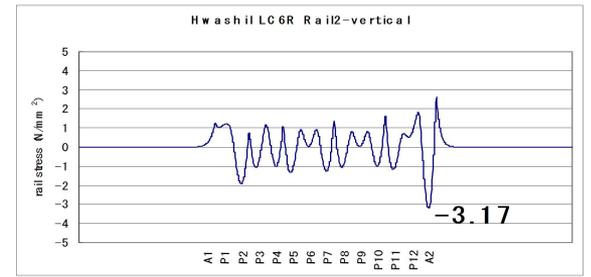
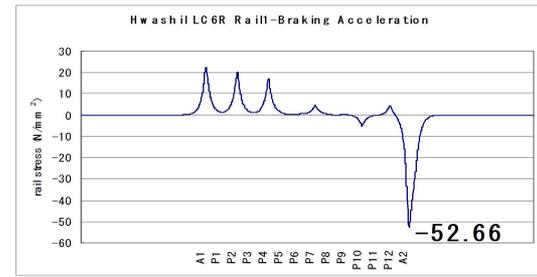
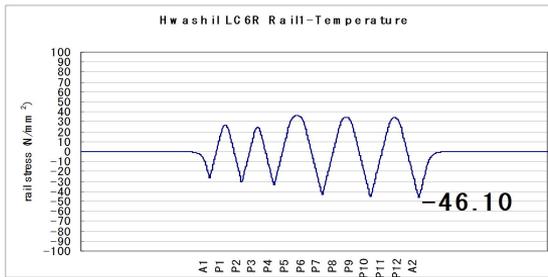
# Results plots in LUSAS



# Results from Simplified Separate Analyses



Sum of temperature and train effects = **-100.32**



Sum of temperature and train effects = **-101.93**

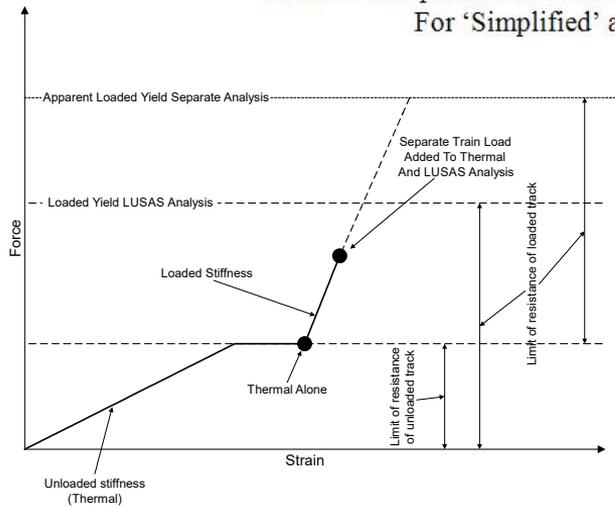
# Simplified or Complete analysis?

- UIC774-3 permits 2 analysis methods:
  - ‘Simplified’
    - Considers temperature, longitudinal and vertical train effects separately and lets them be combined to get a ‘total’ effect
  - ‘Complete’
    - Considers the temperature, and longitudinal and vertical train effects simultaneously
- More accuracy obtained from a ‘Complete’ simultaneous analysis (LUSAS method)

# 'Simplified' / 'Complete' Results Comparison

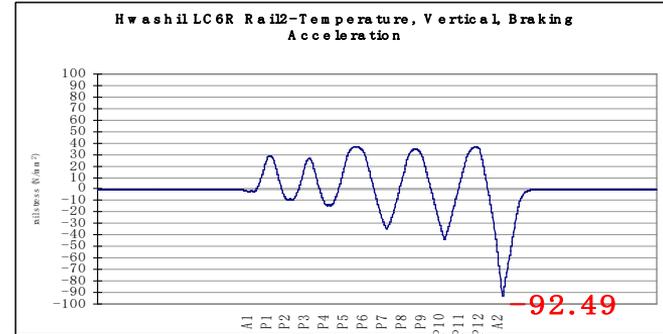
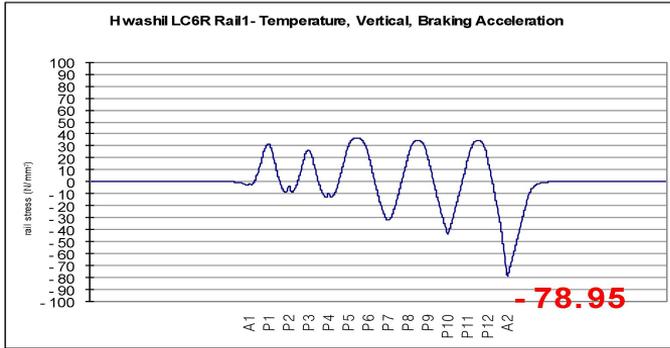
Trainset loading type	'Simplified'	'Complete'	Over-prediction Ratio 'Simplified'/'Complete'
	Separate Nonlinear Analysis Of Thermal And Train Loading	Nonlinear Thermal And Train Loading With Material Change	
Track 1 (Braking)	94.99	79.08	1.2
Track 2 (Accelerating)	103.66	92.58	1.12

Table 1: Comparison Of Peak Compressive Rail Stresses (in N/mm<sup>2</sup>) For Hwasil viaduct For 'Simplified' and 'Complete' UIC774-3 Analysis Methods



*“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.”*

# Results from Complete Simultaneous Analysis



Item				
	Simplified	Complete	Separate	Complete
Temp	-46.10Mpa	<b>-78.95Mpa</b>	-46.10Mpa	<b>-92.49Mpa</b>
Train (longitudinal)	-51.00Mpa		-52.66Mpa	
Train (vertical)	-3.22Mpa		-3.17Mpa	
Sum	-100.32Mpa		-101.93Mpa	
Ratio vs Complete Analysis	127%	-	110%	-



# LUSAS Rail Track Analysis - Benefits

- Automated model building guarantees correctly-built models compared to manual model creation
- Automatically updates the material properties associated with the track/structure interface based upon the position of the passing train or trains
- Provides results in summary, tabular or graphical formats for all or selected parts of the model
- Provides a much faster assessment of thermal and / or train loading track interaction effects on multi-span structures to the UIC774-3 Code of Practice than all other methods

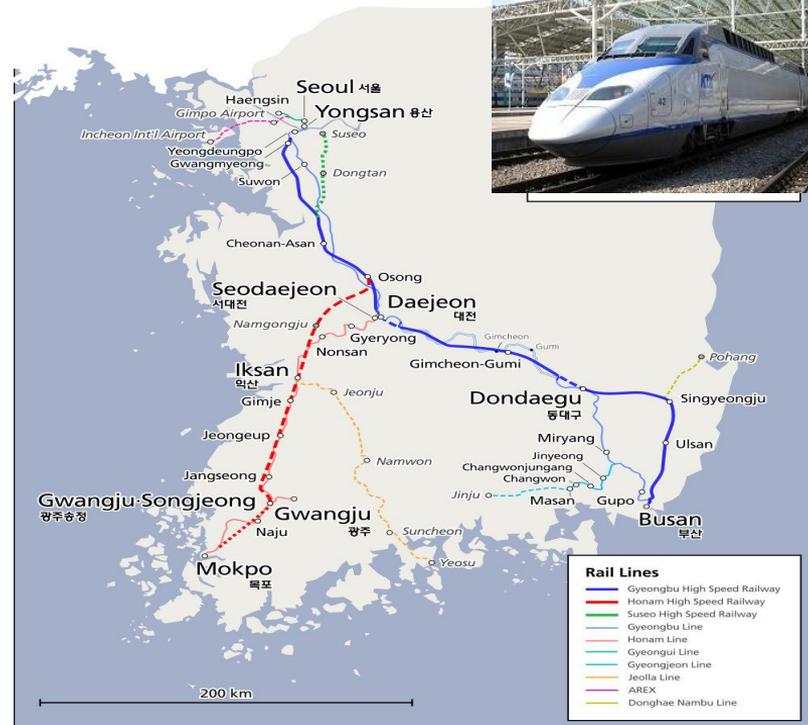
# LUSAS RTA projects in South Korea

## Unballasted track

- All bridges on Gyeongbu High Speed Railway – 2<sup>nd</sup> phase (between Daegu and Busan).
- Some bridges on the Honam HSR
- All bridges on Daegu city rail metro - currently under construction

## Ballasted track

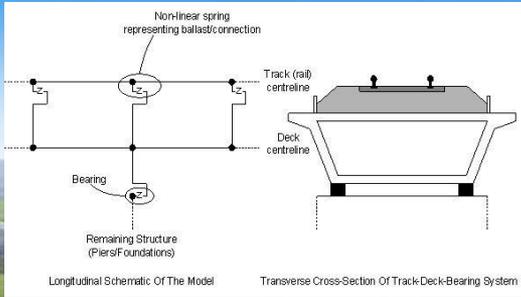
- All bridges on Jeonla railway between Shingpung-Yeocheon
- All bridges on Suin railway between Suwon and Incheon.



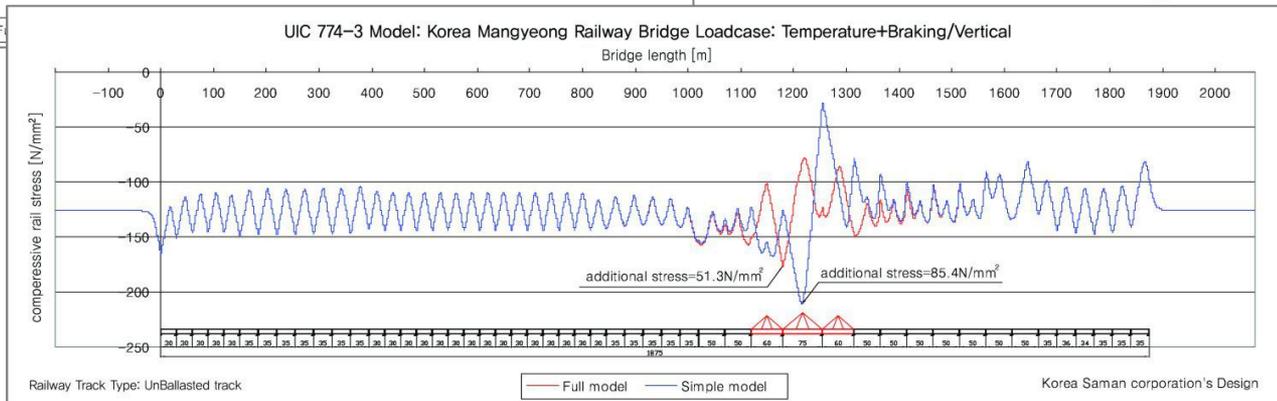
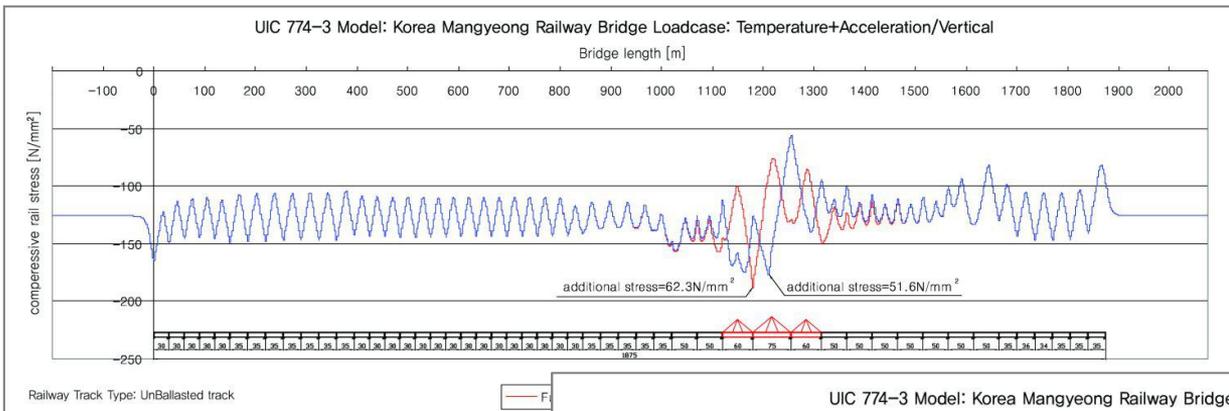
# Gyeongbu High Speed Railway



# Honam HSR : Manyeong Crossing

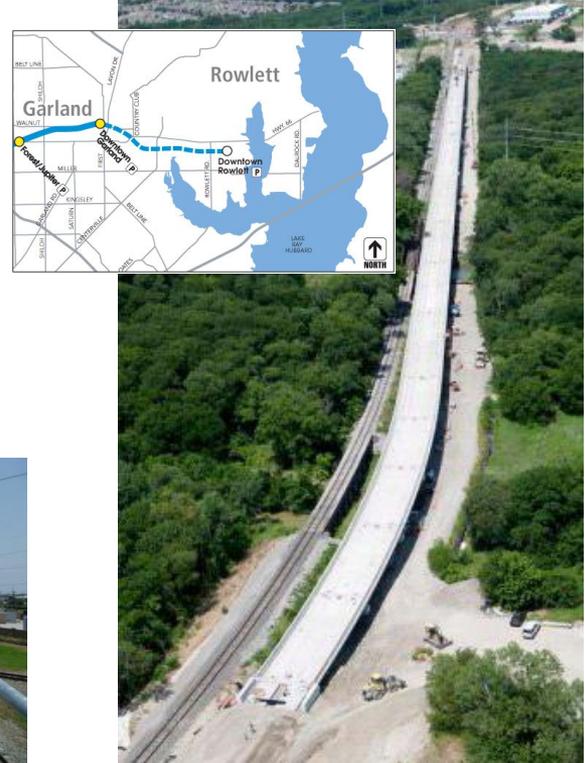


# Honam HSR : Manyeong Crossing



# DART Light Rail System

- Dallas Area Rapid Transit
  - 5 mile / 8 km Blue Line extension
  - 7 new structures required
  - One 28 span and one 11 span bridge assessed for thermal track-structure interaction effects



# Onkaparinga Valley Bridge

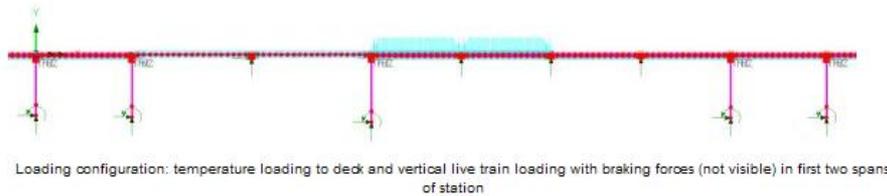
- Seaford Rail Extension, South Australia
  - one of Australia's longest rail bridges at 1.2km in length
  - 35 piers supporting 33m long spans



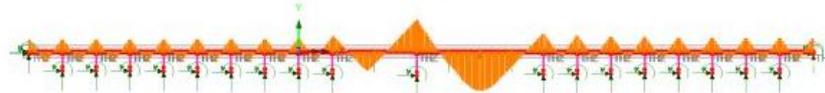
# Dubai Metro light rail project

ATKINS

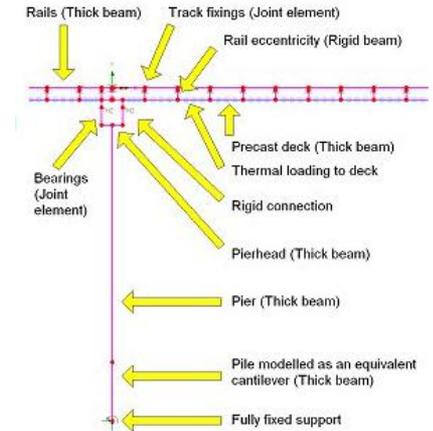
- Example of use of *manually*-created LUSAS models for track structure interaction
  - Done before LUSAS Rail Track Analysis available.
  - Would be greatly simplified now.



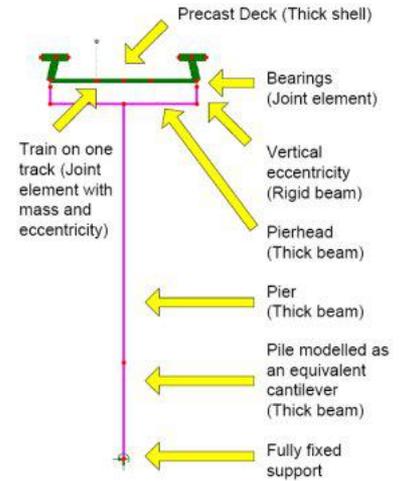
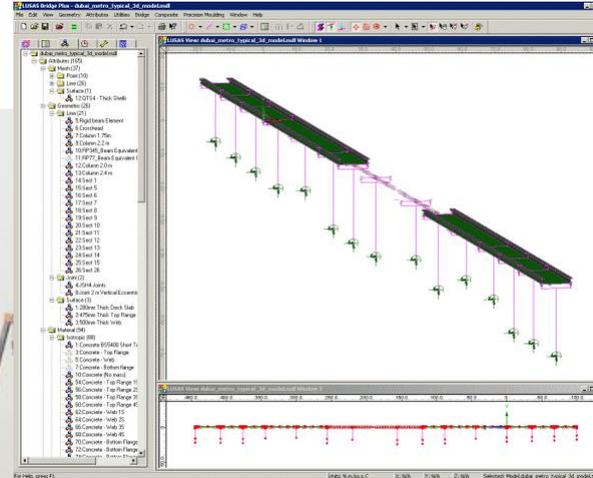
Loading configuration: temperature loading to deck and vertical live train loading with braking forces (not visible) in first two spans of station



Stress in rails from applied thermal and train braking loading

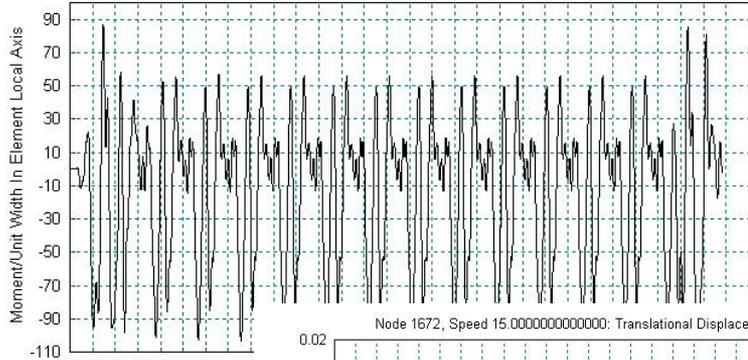


# Dubai Metro - Red and Green Lines

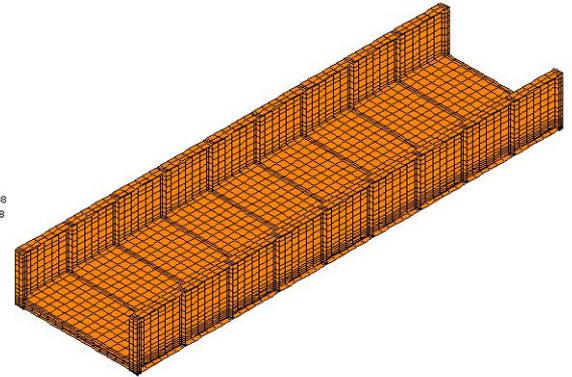
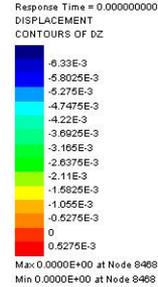
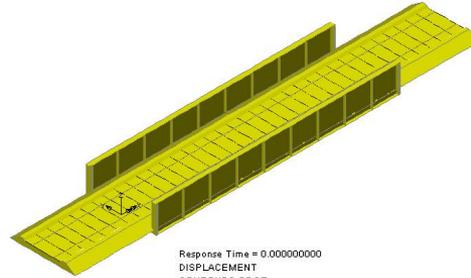
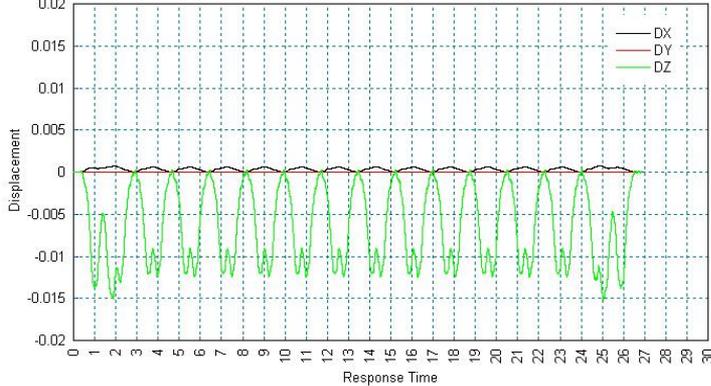


# Dynamics Analysis

Thick Shell Element 1193 Gauss Point 1, Speed 70.00000000000000: Stress Resultant Time History



Node 1672, Speed 15.000000000000000: Translational Displacement Time History



# Rail Track Analysis – In Summary

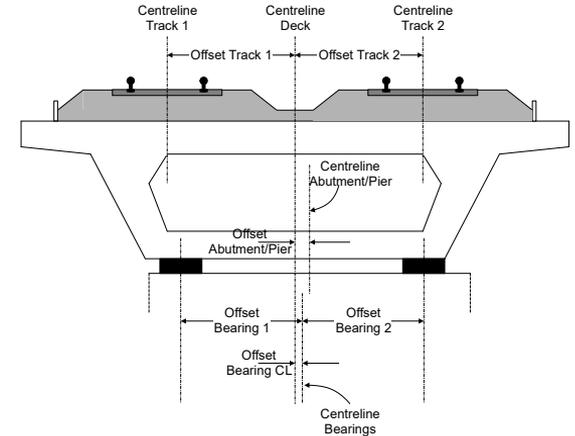
- **Speeds up** the investigation / prediction process
- Allows quick **optimisation of designs**
- **Automated model building** guarantees correctly-built models compared to manual model creation
- Allows the analysis of **multiple trainset configurations** quickly
- Allows **quick extraction and presentation of key results** such as
  - The change in axial stress in the rails
  - The displacement behaviour of the combined track-structure system
  - Support reactions

# In Summary

- Automated model building guarantees correctly-built models compared to manual model creation.
- Automatically updates material properties associated with the track/structure interface.
- Provides results in summary, tabular or graphical formats for all or selected parts of the track/bridge model.
- Provides a faster assessment of track interaction effects for multi-span structures to the *UIC774-3 Code of Practice* than all other known methods.
- Can be used to meet the requirements of *Eurocode EN 1991-2:2003 Eurocode 1: Actions on structures - Part 2: Traffic loads on bridges*

# Current limitations of use

- Offsets are not modelled
- Curved bridges cannot be modelled
- Only 1 or 2 tracks can be considered
- Thermal loading for mixed steel and concrete bridges cannot be generated through the input spreadsheet
  - But is possible by manually editing the built model data



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