Rail Structure Interaction

Case Study Modelling and Benefits

Jeremy Barnes - Associate Director - Hewson Consulting Engineers

Nathan Griffiths - Design Engineer - Hewson Consulting Engineers
Introduction

• Development of Rail Fixings
• The Need for Rail Structure Interaction
• RSI Modelling Issues
• Case Study 1 – Jakarta MRT
• Case Study 2 – North Wales Viaduct
Development of Rail Fixings

- Historically jointed rail used
- Maximum 37m rail lengths
- Fishplate joints with gaps left between rails
- Rail movement accommodated at joints
- No thermal rail stresses built up
- Poor ride quality
- Problematic for track circuits
- Maintenance liability
Development of Rail Fixings

- Continuously Welded Rail Developed
- Joints in rails eliminated
- Long lengths of rail can be used
- Good ride quality
- More compatible with track circuits
- Low maintenance but more expensive to install
- On UK Network most jointed track replaced by CWR
- Thermal stresses built up in the rail
Development of Rail Fixings
The Need for RSI

- CWR designed to resist thermal stresses
- Structure movement increases rail stresses
- Rail re-distributes traction & braking
The Need for RSI

- Lengthy structures traditionally isolated with rail breather joints at ends
- Maintenance liability & rail authorities keen to eliminate
The Need for RSI

- Keep spans short and simply supported
- May not be the most economic structural solution
- Creates a different maintenance liability
The Need for RSI

- Undertake rail structure interaction analysis
- Models effect of structure on rail and vice versa
- Guidance given in UIC774/3 & EN 1991-2
RSI Modelling Issues

- Rail to Structure Connection is non-linear
- Represents the build up of resistance and slip of connection
- Different frictional values for loaded and unloaded track

Ballasted Track Bi-linear Springs

- Resistance of the track, $k$ [kN/m]
- Displacement [mm]

Graph showing the behavior of the track with displacement, indicating different stiffness for unloaded and loaded conditions.
RSI Modelling Issues

- Different stiffness values for ballasted and direct fixing
- Different frictional values for loaded and unloaded track
RSI Modelling Issues

- Long lengths to be modelled to minimize end effects
- Abutments, station structures and embankments are stiff elements
- Traction and braking forces are attracted to these elements
RSI Modelling Issues

- Limitations on rail curvature in UIC774 & BS EN 1991-2
- Rail curvature limited to 1500m radius
- Derogation required in UK to use on curved track with a radius less than 1500m
- Additional lateral restraint required or reduced allowable stresses
Case Study 1 – Jakarta MRT

- Mass Rapid Transit (MRT) Line in Jakarta, Indonesia
- 4.7 km of viaduct decks typically double tracks
- 4 elevated stations
Case Study 1 – Jakarta MRT

- Precast segmental internally prestressed
- Simply supported spans, typically 36.65m
Case Study 1 – Jakarta MRT

- Direct Fixing track
- Fully CWR – no breather joints
- UIC 54 rail
Case Study 1 – Jakarta MRT

- 3D Model of rail and viaducts developed
- Stiffness of the rail, superstructure, substructure and stations are modelled
## Case Study 1 – Jakarta MRT

- Rail stresses

<table>
<thead>
<tr>
<th>Action</th>
<th>Value</th>
<th>Permissible stress (UIC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>+/- 41 N/mm²</td>
<td>72 N/mm² (Compression)</td>
</tr>
<tr>
<td>Rail traffic</td>
<td>+/- 26 N/mm²</td>
<td>92 N/mm² (Tension)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>+/- 67 N/mm²</td>
<td></td>
</tr>
</tbody>
</table>
Case Study 1 – Jakarta MRT

- RSI – decrease in bearing forces
- More economical bearing design

![Bar chart showing longitudinal bearing forces from railway secondary loads with and without RSI.](chart.png)
Case Study 2 – North Wales Viaduct

- Single track bi-directional line in North Wales
- Significant Rail curvature with track lateral restraints
- Low speed line
Case Study 2 – North Wales Viaduct

- Multi-span concrete beam and slab bridge over river
- Fully integral piers to eliminate bearings
- Thermal movement of piers affects rail stresses
Case Study 2 – North Wales Viaduct

- Fully integral abutments
- Sleeved piles at abutments to allow movement
- Pway supported on embankment behind
Case Study 2 – North Wales Viaduct

- 3D MIDAS model of rail and structure developed
- Rail and structure connected with MIDAS multi-linear springs to model track bi-linear stiffness relationship
- Multi-linear springs at 1m centres
Case Study 2 – North Wales Viaduct

- Stiffness of abutment modelled
- Fill resistance behind abutment modelled
- Embankment modelled as stiff restraints
Case Study 2 – North Wales Viaduct

- Lower and upperbound models developed to reflect variability in ground conditions
- Lowerbound model included design effects of scour
Case Study 2 – North Wales Viaduct

- Rail stresses

<table>
<thead>
<tr>
<th>Variable action</th>
<th>Bi-linear Spring</th>
<th>Upper / Lowerbound</th>
<th>Stress N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Expansion</td>
<td>Unloaded</td>
<td>Upper</td>
<td>60 (tensile)</td>
</tr>
<tr>
<td>Thermal Expansion</td>
<td>Unloaded</td>
<td>Lower</td>
<td>65 (tensile)</td>
</tr>
<tr>
<td>Thermal Contraction</td>
<td>Unloaded</td>
<td>Upper</td>
<td>45 (compressive)</td>
</tr>
<tr>
<td>Thermal Contraction</td>
<td>Unloaded</td>
<td>Lower</td>
<td>50 (compressive)</td>
</tr>
</tbody>
</table>
Case Study 2 – North Wales Viaduct

- RSI distributes horizontal loads to all piers and to the embankments
Conclusions and Benefits

• RSI analysis opens up the use of multi-span continuous construction
• RSI analysis can allow integral construction to be used
• RSI offers economies as longitudinal forces are distributed over longer lengths reducing the forces on piers and bearings
Thank you