Need for Rail Structure Interaction for Railway Bridges Having Continuous Welded Rails

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Abstract— In case of Metro Railway bridges, the widely used Continuous Welded Rail (CWR) is directly fastened to the concrete block placed above the bridge deck with the help of Rail Fasteners. Hence, there is a need of detailed study to understand the transfer of forces between deck and rail and also to the substructure in terms of Rail Structure Interaction phenomenon. In this paper, comparison of two different railway bridges i.e. one with Rail Structure Interaction and other without Rail Structure Interaction is studied in terms of additional stresses in the rail. The connection between deck and rail is done with the help of Multi linear Elastic Link and Rigid link to study the effect on the structure. This paper also illustrates the amount of additional rail stresses generated for model with rail Expansion Joint (REJ) and model without REJ (Continuously Welded Rail) to study need of axial rail stresses using software MIDAS Civil 2014.

Keywords: Continuous Welded Rail (CWR), Rail Expansion Joints (REJ), MIDAS Civil 2014, Metro Bridges

I. INTRODUCTION

Due to temperature and braking/vertical loading variations, considerable longitudinal rail stresses and displacement may develop in the Continuous welded Rail (CWR) track on long span bridges. Generally these types of problems are solved using Rail expansion joints (REJ) for normal railway bridges. In case of metro bridges, the CWR track is generally used, so there is no REJ to distribute the rail stresses to the deck and also to the substructure. Thus, additional stresses in the rail are generated due to different loading on the rails. Figure 1 shows the interaction model between bridge and the track.

A. Necessity of Continuously Welded Rail (CWR):
- The reduced impact force in the rails increases the life span of the rails and improves the ride quality.
- The decreasing noise and vibration by the reduced impact force is less impeding the ambient environment.
- Reduces track maintenance.
- Eliminates the joints that cause rail fatigue.
- Improves track safety.
- Limits the wear of rolling stock.

As temperature changes, the superstructure (deck and girder) expands or contracts as rail is basically stationary because of their continuity throughout the length of bridge. This thermal action exerts interactive additional forces and displacement on the rails and superstructure. Figure 2 shows the axial forces in CWR track on bridge due to thermal load.

Fig. 1: Interaction model between bridge and the deck
(1) Track (2) Superstructure (a single deck comprising two spans and a single deck with one span shown) (3) Embankment (4) Rail expansion device (if present) (5) Longitudinal non-linear springs reproducing the longitudinal load/displacement behaviour of the track (6) Longitudinal springs reproducing the longitudinal stiffness \( K \) of a fixed support to the deck taking into account the stiffness of the foundation, piers and bearings etc.

Fig. 2: Axial forces in Continuously Welded Rail (CWR)

The elastic fastening is used to hold the rail down to the track using elastic tension claps which have certain resistance to movement of the rail and is directly related to the load applied by this tension claps. After the threshold resistance of this fastening is reached, the rail slip and applies a constant load to the track structure as shown in the figure 3. In case of non ballasted track, all the longitudinal resistance is offered by the fastening and transmit the load from the bridge to substructure and also from bridge to the track by using Multi Linear Elastic Link.

Fig. 3: Bilinear behaviour of the track.
II. COMPARISON OF MODEL WITH & WITHOUT RSI ANALYSIS

In case of Elevated metro railway project, analysis is carried out in a similar way not considering the effect of rail structure interaction of forces and displacement between the rail and the structures and thus amount of additional stresses in the rail is not taken into consideration. This paper investigates the amount of additional stresses generated while performing RSI analysis.

A. General Description of Model:
The model consists of 30 m simply supported span Prestressed Concrete deck having embankment of 300 m on both sides of the deck having total length of 630 meters. The left end of the deck is kept fixed while other end is roller end.

B. Assigning Boundary Conditions:
1) Model without Interaction:
In case of model with interaction, rigid connection is provided between the deck and the rail by using the Rigid Link between the deck and rail (restrained in all the direction) as well as rigid connection between top and bottom of the deck as shown in the figure below.

2) Model with Rail Structure Interaction

In case of model with interaction, Bi-Linear links are defined between the deck and the rail to simulate the loaded and unloaded conditions of the train load using the Midas CIVIL Multi-Linear Elastic Link function.

The bilinear stiffness of ballasted as well as unballasted track is mentioned below:

<table>
<thead>
<tr>
<th></th>
<th>Ballasted Bed</th>
<th>Concrete Bed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral Limit Displacement $U_d$</td>
<td>$= 0.002$ m</td>
<td>$= 0.0005$ m</td>
</tr>
<tr>
<td>Unloaded Condition</td>
<td>$= 20$ kN/m</td>
<td>$= 40$ kN/m</td>
</tr>
<tr>
<td>Loaded Condition</td>
<td>$= 60$ kN/m</td>
<td>$= 60$ kN/m</td>
</tr>
</tbody>
</table>

C. Assign Loading:
1) Temperature loading
   - Deck temperature $= 35^\circ$ C
   - Rail temperature $= 50^\circ$ C

2) Vertical Train Loading
   - 4 Axle car with load per axle of 17 tonnes (170 kN) is considered
   - Length of one car $= 25$ m
   - Vertical Train Load $= 4 \times 170/25 = 27.2$ kN/m (for maximum length of 200 m)

D. Summary of Results:

<table>
<thead>
<tr>
<th>Item</th>
<th>Analysis without Rail Structure Interaction</th>
<th>Analysis with Rail Structure Interaction</th>
<th>Percentage Increase in the results wrt results with interaction</th>
<th>Justify whether RSI is needed or not</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial stresses in the rail due to train vertical load</td>
<td>5.72 N/mm$^2$</td>
<td>14.44 N/mm$^2$</td>
<td>60.38 %</td>
<td>Yes</td>
</tr>
<tr>
<td>Axial stresses in the rail due to temperature loading in the deck and rail</td>
<td>42.6 N/mm$^2$</td>
<td>59.6 N/mm$^2$</td>
<td>28.52 %</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 1: Summary of results for justification of RSI is needed or not.

III. COMPARISON OF MODEL WITH REJ & WITHOUT REJ

A. General Description of Model:
In this paper, the general descriptions i.e. span length, rail and deck properties, boundary conditions and loading remains same of mentioned above. The two models is prepared, one of which is provided with the Rail Expansion Joint (REJ) at the middle of the span length and other is not having REJ anywhere throughout the span. Thus, the comparative study of these two models is done in order to comment on the rail stresses generated in case of continuous track without any rail expansion joints.
B. Summary of Results:

![Graph showing rail stresses comparison](image1)

**Fig. 6:** Comparison of Rail stresses for Rail with expansion joints and CWR for the temperature loading.

![Graph showing rail stresses comparison](image2)

**Fig. 7:** Comparison of Rail stresses for Rail with expansion joints and CWR for the Train loading.

IV. Conclusion

Following conclusions can be drawn:

- By Comparing the Rail stresses for model with & without RSI Analysis, there is significant amount of increase in the percentage of rail stresses for vertical train as well as temperature loading, thus is necessary to carry out rail structure interaction.
- In the case of with & without Rail Structure Interaction problem, there is about 60.38% increase in the rail stresses due to train vertical loading & 28.52% due to thermal loading.
- It is noted that axial stresses reduced to zero at the location of Rail Expansion Joint (REJ) as compared to CWR at that particular location stating that there is reduction in axial stresses when REJ is used. This shows the need for consideration of RSI when CWR is used without REJ.

REFERENCES