A REVIEW ON RAIL STRUCTURE INTERACTION ANALYSIS OF METRO BRIDGE

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Abstract
Continuously welded rails (CWR) with a straight track leading to the concrete deck are used in the majority of subway bridge developments. Temperature variations, rail loads (braking/traction and vertical loads) directly induced by the rail fasteners, and the interaction of the CWR and the elevated rail structure as a result of driving relationships are examples of non-linear forces. No obstacles to this impact, such as superstructure type, span, clearance, deck bending stiffness, or reinforcing stiffness, exist, according to UIC 774-3R. This study looks at how metro bridges interact with one another and analyzes DN Nagar - Mandale, Mumbai, as a case study of continuous bridge connectivity. The steel bridge makes up 260.43 m of the overall length examined in this study; the remaining length is made up of the U-shaped beam and PSC beam superstructure along the border. SOFiSTiK software is used for three-dimensional (3D) finite element analysis. The study's findings, which were tested to the permissible limits of UIC 774-3R, are displayed in terms of axial rail stress along the length of the bridge.
Keywords — Rail structure interaction; Continuous welded rail; Metro bridge; UIC 774-3R

I. Introduction

Continuously welded rails, or CWR rails, are popular and offer a number of benefits. When compared to patchwork pallets, CWR prolongs the life of pallet products, lowers maintenance costs, and boosts operational effectiveness. The elastic CWR, the elastic fasteners that secure the screws in the bridge deck's foundation, the superstructure, the equipment, and the elastic bearings that support the equipment's superstructure (together with the base) are the primary parts of the CWR bridge. relationship between the train and bridge structures as a result of crashes, temperature fluctuations, and vertical train movements. The structure and the screws are under more stress as a result of the rail-bridge interaction. Taking into consideration the nonlinear stiffness law, rail fasteners play a major role in the interaction between the rail and the structure.

Since fasteners do not expand or contract in response to changes in bridge temperature, CWR fastens them directly to the deck of the bridge. Tensile force builds up on the rail when the temperature falls below that of the rail, breaking the train. When the temperature rises above that of the rail, force is generated in the rail, forcing it to bend. Furthermore, because of the influence of flow and structure, rotational and longitudinal shear forces arise at the load-bearing level. These forces must be included in the process design of the infrastructure and foundation. This article only examines the nonlinear relationship between the track and the bridge deck as well as the piers' shear strength, which should be taken into account when designing the bridge. The interaction model of the steel composite bridge's infrastructure and foundation is analyzed using SOFiSTiK software.

II. Literature

The study of CWR forces and their impact on design has been discussed nationally and internationally for the last 30 years.

1. P. Ruge, C. Birk, Longitudinal forces in continuously welded rails on bridge decks due to nonlinear track bridge interaction The railway bridge's welded rails' longitudinal strains are displayed. The railway's braking action causes long-term loads, not the bridge's temperature change or the abrupt shift in ballast hardness that happens as a train over it. The study's conclusions indicate that the long-term stress derived from the conventional loading procedure by itself is greater than the stress derived from

the appropriate combination of the suggested shipping data. On the basis of the findings, it was occasionally determined that permanent equipment was not required. Based on real demand and non-linear simulation, the maximum rail pressure is decreased.

2. D.R. Widrda, P. Ruge, C. Birk, Longitudinal track bridge interaction for load sequence It was discovered that the maximum compression force rose by 10% as a result of the change in joint stiffness and that the results obtained by the static approach were sufficiently accurate. Additionally, the loading-unloading paths' linear elastic component along the line-bridge connection interface rose after summer, according to the authors' findings.

3. Roman Okelo, Afisu Olabimtan, Nonlinear rail structure interaction analysis of an elevated skewed steel guideway. The calculation of railway breaking spacing, the value of railway axial stress and load capacity, and their distribution over the length of the bridge are the main topics of this article. It was consequently concluded that there was very little external force transmitted from the supports to the substructure. Studies have demonstrated that 3D models can offer a more comprehensive comprehension of RSI strength. The writers came to the conclusion that the rail clearance ought to be lower than what the design called for.

4. Fryba, Experimental Research of thermal interaction of long welded rails with railway bridge. Three steel bridges on the National Railway with long welded rails were used for research trials. Theoretical measurements and actual railway pressure and displacement values agree. He proposed that other factors are difficult to determine, aside from the orbital resistance k, which is dependent on a variety of factors and varies from the orbit.

5. Simoes, Calcada and Delgado, Track-bridge interaction in railway lines: Application to the study of the bridge over the river Moros. The 476-meter-long bridge that spans the Moros River is where the rail-bridge interaction takes place. The rail axial force and reinforcement reaction results were shown to be positively impacted by the stiffness of the abutment/foundation group. In the embankment area, a road must be at least 200 meters long.

6. Reis, Lopes and Riberio, Track Structure interaction n long railway bridges. Numerous influences have been taken into consideration when studying the design concept for lengthy railway bridges. Bridge design solutions in seismic regions need to strike a balance between the benefits of short-span spans and minimizing joint interaction with the challenge of conveying seismic forces to lower piers. Give design options for two viaducts in seismically active areas that have poor geotechnical characteristics. For braking loads, higher axial forces are obtained at the track's fulcrum connections.

7. Hess, Track Bridge Interaction Analysis Using Interface Elements Adaptive to various Loading cases. The rotation of the bridge end will result in a significant lifting force on the road if continuous joints are fitted at its end. The runway's stability could be impacted by this. Support screws on the transition plate supported by the bridge end and abutment can lessen the angle shift of the bridge end.

8. Dutoit, New evolution for high speed rail line bridge design criteria and corresponding design procedures. There is a discussion of some recent advancements and existing designs for railway expansion joints. The rotation of the bridge end will result in a significant lifting force on the road if continuous joints are fitted at its end. The runway's stability could be impacted by this. In this instance, abutments and the replacement plate support screws can be used to lessen the angle shift of the bridge end.

III. CASE STUDY OF BRIDGE STRUCTURE

Bridge for Mumbai Metro Line 2B from D.N. This study's foundation was the distance between Mandale and Nagar. Two rows of multi-span steel composite beams that only support the superstructure make up the bridge's construction. U-shaped beams, prestressed prestressed beams, and post-tensioned prestressed beam superstructures are the three primary types of steel beams. Two rails are fastened to the deck immediately on all major walkways. Fasteners positioned at regular intervals along the rope's length anchor screws to the deck. Scaffolds made of reinforced concrete (RC) are rectangular for the steel composite and PSC superstructure and circular for the U-beam superstructure.

The panels made of stone make up the foundation. The steel bridge makes up 260.43 m of the overall length taken into account in this analysis; the remaining length is made up of the PSC beam superstructure span and the U-shaped beam.
As indicated by the general diagram, the substructure is taken into consideration at various heights, and the superstructure under consideration in this study has a total of 23 spans with varying spans. The bridge's curvature is measured in order to ascertain the precise curvature of the designated steel connection. POT-PTFE supports hold up the post-tensioned beam superstructure, while elastomeric supports and steel composites support the U-beam and prestressed beam superstructure. The two extension bulbs are separated by a 50 mm telescopic gap. The conventional U-beam span was comprised of four 1 m diameter piles and two m diameter circular piers. In the particular aperture, six scaffolds measuring 2.2 × 2.4 m in diameter and height are utilized.

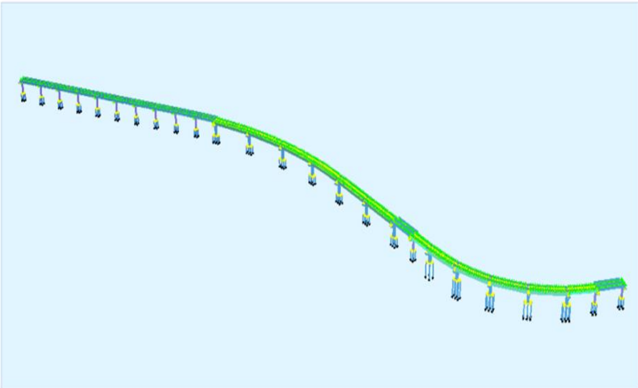

Fig 1:- Perspective view of Bridge

IV. NUMERICAL MODELING OF TRACK BRIDGE INTERACTION

A numerical model was created and utilized for the purpose of performing a numerical analysis of the RSI of steel composite metro bridges. Figure 1 displays the interaction-interaction model that was created. Solid process-based program SOFiSTiK was used to create this mathematical model, which simulates the interaction model. Beams were used to represent the bridge and screws, while nonlinear lines were used to represent the link between the two. The bilinear elastic-plastic law, which is characterized by the maximum friction force and the output value u0, is applied to the experimental data. According to UIC 774-3R,

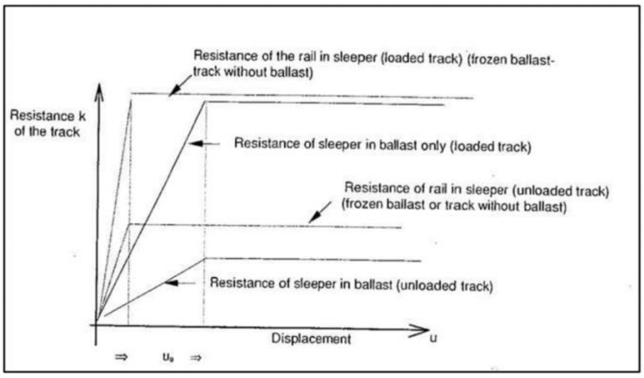

Fig 2:- Force-displacement interaction law between track and deck

shift in the elastic and plastic zones 0.5 mm is u0.
Resistances k for a single track in the plastic zone per unit of length:
- For an unloaded track, ktr = 40 kN/m (80000 kN/m/m).
- For a loaded track, ktr = 60 kN/m (120000 kN/m/m).

Figures 3 and 4 below illustrate how the connection between the superstructure and rail is represented as a spring with bilinear elasto-plastic behavior in the transverse direction and stiffness using the force displacement diagram mentioned above.

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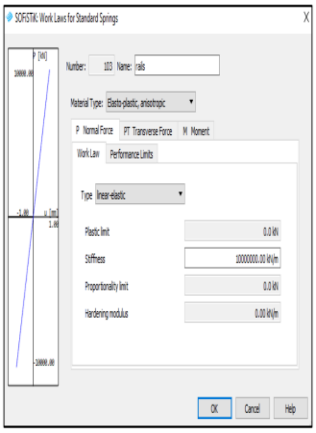
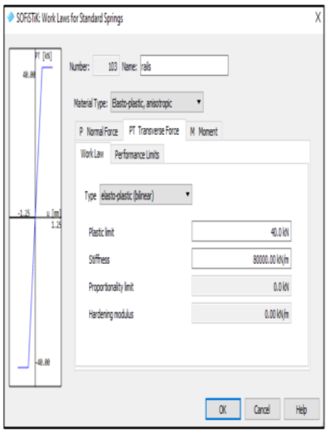

Fig 3:- Definition of normal force of rail spring in SOFiSTiK Fig 4: Definition of trans. force of rail spring in SOFiSTiK

V. LOADS AND ACTION

5.1 Case of loading 1. Thermodynamic effects in the integrated track and structural system

a. Rail In the event of CWR, a change in track temperature does not result in a shift in the track, according to UIC 774-3. Therefore, the temperature change in the track has no interaction impact.

b. Superstructure: The temperature load of ± 35°C has been applied to the superstructure in accordance with clause 1.4.2 of UIC 774-3R.

5.2 Load case 2: Effects of live loads on rails

In accordance with UIC 774-3R section 1.4.3, loads from a maximum of two tracks shall be taken into account for the analysis. Additionally, the same clause states that traction on the second track and braking on the first circuit will be taken into account.

a. Effects throughout time

In SOFiSTiK, the moving load definition is utilized in conjunction with braking and traction effects. Both traction and braking are regarded as 20% of the vertical axle load to be on the safe side.

b. Vertical Impact

The deck bends as a result of traffic pressures. This causes the upper edge of the deck to shift and the end parts to rotate. It is necessary to assess the impact of this rotation on the rails. For the analysis, a single six-coach train with four axles per coach as specified by DBR has been taken into consideration. A single metro rail car's vertical load is depicted in fig. 6 below. There are six cars in the Mumbai metro; each vehicle is 22.1 meters long and can carry 680 kilograms.

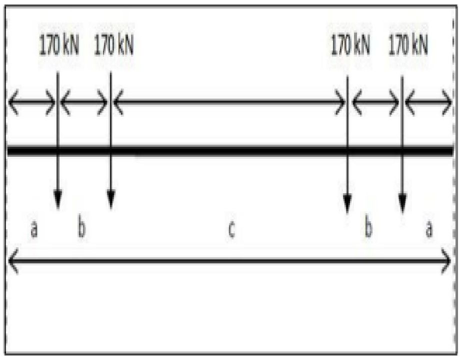

Fig 5: Vertical load of train

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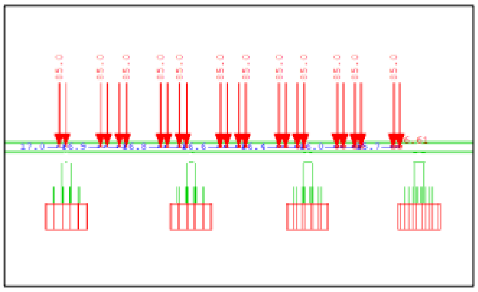

Fig 6: Vertical, braking and acceleration applied in SOFiSTiK

VI. RESULTS AND DISCUSSION

The Steel Composite Mumbai Metro line 2B rail bridge's rail structure interaction analysis is carried out in this case study, and the findings are displayed for each load. Results about how forces transmitted to the substructure are affected by rail continuity are also shown.

6.1 Increased strains in rail as a result of temperature fluctuations The following figures illustrate the axial force in a rail as a function of temperature.

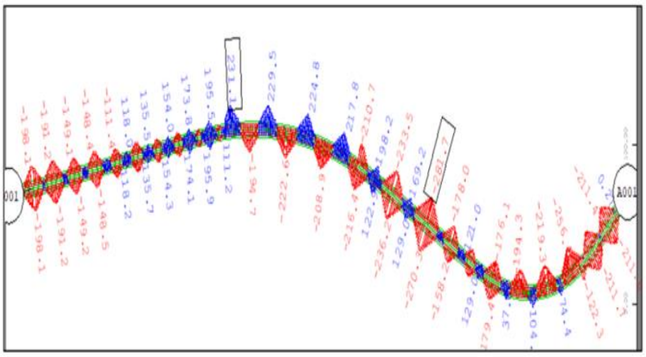

Fig 7: Axial tension force in rail due to temperature variation

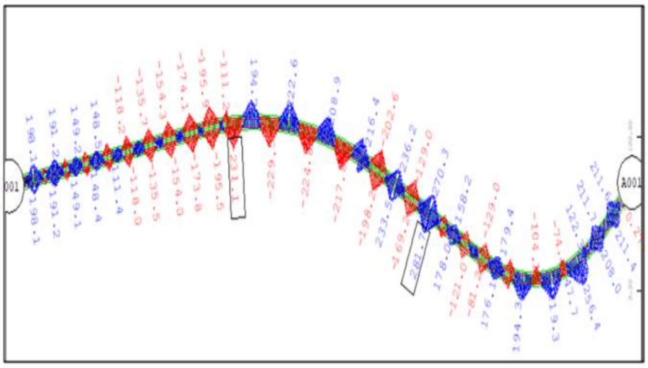

Fig 8: Axial compression force in rail due to temperature variation

6.2 Additional stresses in rail due to live load

Figure 10 below illustrates the essential live load point for the controlling forces in the steel composite span's rail. When the main line's two tracks are loaded, this is the crucial situation. This load considers the rotation of the span resulting from vertical loads as well as the longitudinal force caused by braking and traction.

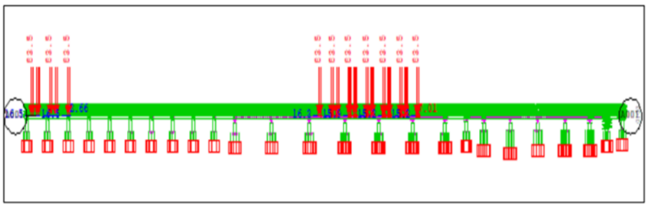

Fig 9: Critical live load position for steel composite span

The axial force in rail due to braking/traction and vertical live loading are shown in the below figures.

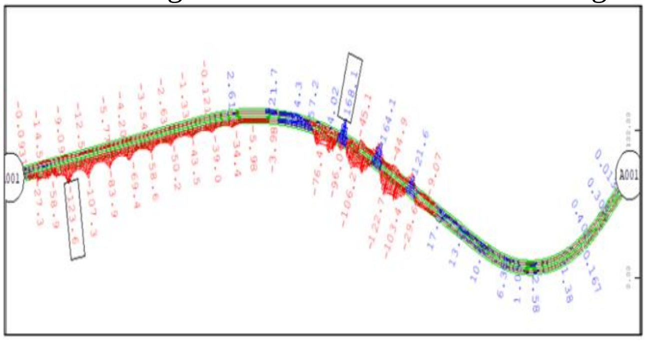

Fig 10: Axial tension force in rail due to live load

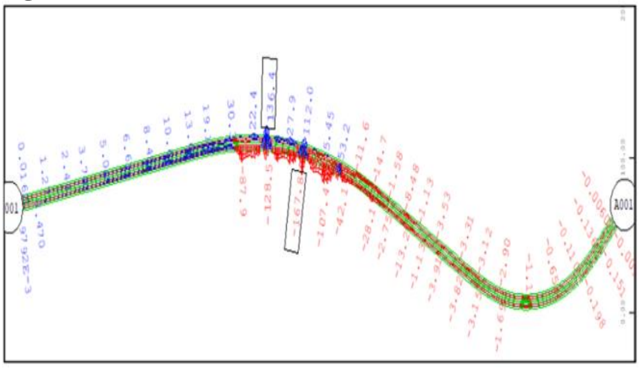

Fig 11: Axial compression force in rail due to live load

VII. Conclusion

1. The overall axial pressure and tensile rail stresses resulting from temperature changes, braking/traction, and vertical movement loads are 52.00 MPa and 52.04 MPa, respectively, according to the rail structure analysis for this study. The rail voltage falls between the allowed ranges in UIC 774-3R. Therefore, extending the walkway is not necessary. The voltage can be lowered by offering expansion devices or adjusting other characteristics (such personal, long-term expansion) if it surpasses the allowable limit specified by UIC 774-3R.
2. The substructure receives a unidirectional horizontal force (LWR) of 3.41 kN/m from the road-structure interaction at varying loading loads. The design of the foundation and substructure must account for LWR forces.

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