The Effect of Wheel Loading on a Railway Bridge: A Case Study on Minnamurra Railway Bridge

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Background

✓ New South Wales, Australia alone has nearly 5000 bridges with 17% being older than 50 years old.

✓ Over the last century, the transportation industry has increased the load for bridge structures which has caused a significant impact to the design life.

✓ Not only loading, many studies have been conducted showing that poor detailing, imperfections, weld defects and holes can significantly reduce the design life of the structure.

✓ Australia’s maturing locomotives and railways concerns with faster and heavier loads will have negative effects to the railway infrastructure.

✓ This will accelerate the deterioration of the railway system and increase the chance of cracking from the sleepers and/or damage to the rail and fastening system failure.
The aim of this project is to **investigate** the effect of **wheel loading** on the interaction between sleepers and railhead in the rail component system for Minnamurra Bridge in Kiama NSW.
Detail of Minnamurra Bridge

Concrete Pier

Railway Line

Concrete

Transoms

Top view of box girder

Section view of box girder with railway line

Introduction

Finite Element Model

Results and Discussion

Conclusions
Finite Element Model - Parts

- Parts
- Concrete pier
- Bracing used in box girder
- Abutment
  - T-sections at top and bottom
  - Bracing used in box girder

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Finite Element Model - Parts

Abutment

Steel plate for box girder

Concrete pier
Finite Element Model – Contact and Interaction

Sleepers and Steel Rail

Tie Constraints

Sleepers used hard contact

Sleepers used tie contact

Surface to Surface Contact
Railway traffic axle loads of 300LA (AS5100.2 Cl 8.2)
Finite Element Model – Loading Condition

Location of load cases considered for the FE analysis of Minnamurra Railway Bridge
Finite Element Model – Boundary Condition

Minnamurra Railway Bridge
Finite Element Model – Material Properties


<table>
<thead>
<tr>
<th>Material</th>
<th>Rail Steel</th>
<th>Steel Plates/Angles</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E$ (MPa)</td>
<td>60,000</td>
<td>200,000</td>
</tr>
<tr>
<td>$\nu$</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>$f_y$ or $f_c'$ (MPa)</td>
<td>320</td>
<td>320</td>
</tr>
<tr>
<td>$f_u$ (MPa)</td>
<td>410</td>
<td>410</td>
</tr>
</tbody>
</table>
Concrete:

- Compressive strength, $f'_c = 40\text{MPa}$
- Young’s Modulus of Concrete, $E_c = 30,000\text{MPa}$
- Poisson ratio = 0.35
- Behaviour of concrete in compression is assumed to be linear up to 40% of the compressive strength ($f'_c$)

Stress-strain relationship of concrete, (Carreira & Chu 1985)
Behaviour of Railway Track

First wheel of each load cases

Second wheel of each load cases

Third wheel of each load cases

Fourth wheel of each load cases

Stress (MPa) vs. Time (STEP) graphs for different load cases.
Behaviour of Railway Track

Stress distribution at Load Case A

Maximum stress
Horizontal Sleeper Movement

Displacement Versus Time

Stress Versus Time

Fixed Sleepers

Pinned Sleepers

S, Mises
(Avg: 75%)
+1.170e+01
+1.072e+01
+9.750e+00
+8.776e+00
+7.803e+00
+6.830e+00
+5.856e+00
+4.883e+00
+3.910e+00
+2.937e+00
+1.963e+00
+9.900e-01
+1.670e-02
Rail and Sleeper Behaviour at Box Girder and Abutment

Location between Abutment and Box Girder

- Box girder
- Rail
- Sleeper
Rail and Sleeper Behaviour at Box Girder and Abutment

Displacement distributions of rail and sleeper at the location of girder and abutment

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Conclusions

From the project herein, it can be conclude that:

➢ This project effectively studied the effects of wheel loading on the existing railway components of the Minnamurra Railway Bridge, using finite element software ABAQUS where included the current wheel loads according to the Australia Standard.

➢ The critical component of the railway bridge was determined to be the rail of the bridge as it experiences high levels of stress. The stress on the rail is close to the yielding limit of the rail material.
Conclusions

➢ The results showed a maximum stress of 320 MPa at the point of the wheel rail contact at each load location of the train and carriages.

➢ The maximum vertical displacement across the railway bridge was 3 mm.

➢ It was found that the rail will no longer be adequate to support increasing loads of future trains.
Recommendations

➢ Steel Rail require upgraded from 60kg to 68kg. This will ensure that the rail can withstand faster and heavier locomotive and also to safeguard passengers and assets into the future.

➢ Improvement of the cross sectional shape of the rail head is recommended where the width of the rail heads base, will reduce the likeliness of buckling.

➢ Due to the age of the Minnamurra Bridge, wear on the steel rail has occurred caused the rails undergo deformation that may cause wheels slip off. Therefore, regular maintenance is recommended to maintain full integrity of the rail.
The authors would like to acknowledge the technical support provided by Transport for New South Wales and Western Sydney University for providing a conducive environment for this project.
QUESTIONS