Low Carbon Railways

Zac: Sakdirat Kaewunruen

BE Hons (Civil), ME, PhD, GCert (Business) MIEAust, CPEng, NPER, RPEQ

Senior Lecturer in Railway and Civil Engineering
Railways NOW & FUTURE

Ballasted Tracks

Horizontal Alignment (top view)

Vertical Alignment (side view)
Slab Tracks
SYSTEMS
NOW & FUTURE
Why we do research?

IMPROVE SAFETY & RELIABILITY
Customers are the centre of everything we do

Zac
analyse geometry and train speed…

Customer wrote
I want faster services!

Zac
research and development on rail infrastructure…

IMPROVE SERVICE LIFE
Zac
improve wheel-rail and passengers’ comfort… :D

Zac
research and development on rail noise and vibration…

MITIGATE
NOISE AND VIBRATION

squeal  flanging  impact  rolling
Wheel/Rail Loading (i)

A wheel burn

loss of contact

Remennikov and Kaewunruen (2008) Structural Control & Health Monitoring
Effect of Impact loads on ballast degradation

PRACTICAL PROBLEMS

Rail Squat Strategies
- field investigation ✓
- finite element analysis ✓
- metallurgical studies ✓

damage of components

Kaewunruen and Remennikov (2009) Engineering Structures
Wheel/Rail Loading (ii)

A dipped weld

\[ P_2 \{ F = ma \} \]

Impact Force (kN)

Impact loads due to crossing and turnouts
FEM: ABAQUS, Vampire & NuCars
Vibration mitigation
New component materials
Component Failures
Impact Forces
Ground vibration
Diamond / Slip
Case Study: complex urban double slips

Kaewunruen (2014) Structural Monitoring and Maintenance
PRACTICAL PROBLEMS

Reduction of failures due to crossing and turnouts

Field Trials
Sleeper/bearer pads
Composite bearers

Kaewunruen (2014) Structural Monitoring and Maintenance
Noise measurement classification & detection correlation with parameters

Figure 1: Rail roughness measurement using the Corrugation Analysis Trolley

PRACTICAL PROBLEMS

Concrete Damage Repair
Carbonation
Chloride contamination
Corrosion

Kaewunruen et al. (2014) Frontiers in Materials
PRACTICAL PROBLEMS

OWH Structure Damage
Longitudinal cracks
Corroded bolts
Corrosion
Railway is complex by nature. Construction of railway thus emits significant carbon footprint.

Sus-systems and their components deteriorate under interdependent systemic functions.

Corrective and preventative maintenance is often required, depending on situation.

Unplanned maintenance can cause excessive financial penalties.
2 Types of Constructions

- **Greenfield** = new construction of infrastructure (new asset)
- **Brownfield** = renewal, retrofit, refurbishment or reconstruction of infrastructure (existing asset)
Construction

- Construction of a New Track:
  - Surveying
Construction

- Construction of a New Track:
  - Ballasting [(video)](video)
Construction

- Construction of a New Track:
  - Rail and Sleeper laying
Construction

- Construction of a New Track:
  - Rail and Sleeper laying
Construction

- Construction of a New Track:
  - Resurfacing (alignment adjustment)
Construction

- Construction of a New Track:
  - Tamping (video)
Construction

- Construction of a New Track:
  - Regulating & Blooming (video)
Construction

- Construction of a New Track:
  - Stabilising (0.1-0.5MGT) (video)
Maintenance

- Railway Assets:
  - Tracks
  - Special Trackwork (Turnouts, Yards/Sidings)
  - Signals, Controls & Communications System
  - Overhead Wiring Structures (OHS)
  - Platforms / Stations
  - Bridges & Viaducts
  - Tunnels
  - Airspace Development (Shopping Centre, Busway)
  - Billboards; Buildings; etc.
Track Services

Track Inspections
- Engine Ride
- Track Walking
- Detailed Track Patrol
- Track Inspection Vehicle (Geometry)
- Rail surface testing
- Crossing Inspection
- Crossing Ultrasonic testing
- Survey Mark Review
- Clearance Review
- Rail Creep Measurement
- Bridge Inspection
- Overhead wiring inspection
- Wayside detection systems
- Ride comfort (Customer Experience)
- Etc.....

Track Data Analysis
- Operational Analysis
- Prioritisation
- Assurance & Audit
- Condition Monitoring & Maintenance Analysis
- Scheduling

Track Maintenance
- Planning & Re-Design
- Operations Management
- Logistics and resources
- Maintaining assets:
  - Renew & Repair
  - Restoration
- Commission and Report
Systems-based strategy to achieve carbon-efficiency (i)

- Extensive monitoring and measurements of railway construction management practices were conducted.
- Life cycle carbon emission from plain-line railway renewal activities are assessed.
- Field data suggests the carbon footprint due to ballasted track construction and maintenance is less than that of ballastless tracks over the lifespan.

Krezo et al. (2016) Transportation Research Part D: Transport & Environment
Systems-based strategy to achieve carbon-efficiency (ii)

- Significantly more maintenance emission in ballastless track bed can be observed at the 30 and 60 year interval.

- Emissions from the embodied carbon of railway construction materials are the dominant contributor.

- Prolonging the reconstruction frequency by optimal routine maintenance activities is the key to reducing lifecycle CO$_2$-e emissions.
Systems-based strategy to achieve carbon-efficiency

- Resurfacing machine TJ061 and TJ091 are the most efficient tampers. It is found that although the dual head tamper (TJ096) is more productive, it is not carbon-efficient.

- By adopting the right combination of work equipment, carbon efficiency can be optimised through appropriate use of resurfacing machines.
The overall results exhibit that similar ratios of construction methodologies and activities can result in similar amounts of CO\textsubscript{2} and material emissions, which are linearly dependent on the reconstruction length.

Extensive cost reviews and expert interviews also suggest a strategy that re-constructing multiple special trackworks (i.e. multiple turnout units) should be carried out simultaneously to help reduce CO\textsubscript{2} emissions instead of sequential unit construction.

<table>
<thead>
<tr>
<th>Project</th>
<th>Total CO\textsubscript{2} emissions</th>
<th>Project duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnout</td>
<td>68,097 kg CO\textsubscript{2}</td>
<td>2</td>
</tr>
<tr>
<td>Crossover</td>
<td>65,328 kg CO\textsubscript{2}</td>
<td>2</td>
</tr>
<tr>
<td>Diamond</td>
<td>62,193 kg CO\textsubscript{2}</td>
<td>2</td>
</tr>
<tr>
<td>Multi-unit turnouts</td>
<td>225,317 kg CO\textsubscript{2}</td>
<td>5</td>
</tr>
<tr>
<td>Avg D</td>
<td>45,064 kg CO\textsubscript{2}</td>
<td>1</td>
</tr>
</tbody>
</table>

Table: $E_{ij}$ from machineries and materials used.
The comparative results showed a 31% reduction in CO2 emissions by using this parallel construction strategy and should be considered by construction and rail transport managers to help reduce CO2 emissions from future special trackwork reconstruction projects.

WE ARE UNIVERSITY OF THE YEAR
Thank you for your kind attention.