




## Management of Heat Speed Restrictions on the Victorian Regional Rail Network

RTSA Victoria Division Presentation – 17<sup>th</sup> June 09

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### Birchip – 28/01/09





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Management of Heat Speed Restrictions on the Victorian Regional Rail Network




### Watchem – 27/01/09



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Management of Heat Speed Restrictions on the Victorian Regional Rail Network




### Background

- Heat Speed Restrictions are known as WOLO's in Victoria;
- WOLO's were introduced in the mid 90's to mitigate to risk of buckle related derailments through reducing the consequences of derailment and reduced dynamic vehicle loading reducing the likelihood
- Track installed and maintained correctly to track design and maintenance standards has a low likelihood of buckling;
- WOLO procedures are covered in the Book of Rules. In most cases, a blanket 90km/h speed restriction is applied on specific lines between 12:00 and 20:00 on days where the temperature is forecast to reach or exceed 36°C in that region



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### Project History


- Regional Fast Rail Project
  - Significant modifications to infrastructure, however WOLO's remained unchanged;
  - WOLO's have become a significant problem with reduced unused network capacity and a more significant relative reduction of speed;
- Cost of WOLO's in 07/08 Financial Year:

Region	Annual WOLO Days	Annual Delay Mins	Annual Delay Cost
Northern	55	4985	\$747,750
Western	13	3028	\$454,200
North East	23	1846	\$276,900
South West	15	1466	\$219,900
Eastern	8	1170	\$175,500
<b>Total</b>			<b>\$1,874,250</b>

Data obtained from V/Line with permission




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### Project History

- To investigate the problem, the Department of Transport (DoT) commissioned a review of the management of Heat Speed Restrictions;
- The theoretical review found existing WOLO procedures on upgraded Class 1 tracks overly conservative;
- V/Line undertook a number of the measurements required to validate the findings of the DoT report



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## Overview

- Development of a buckling probability model (Kish)
  - Determining key variables
    - Rail Temperature
    - Misalignment, SFT & lateral resistance distributions
  - Modelling with CWR-SAFE
  - Results
  - Policy Options and Implications



## Rail Temperature

- It is necessary to predict or measure rail temperature to understand the risk of buckling;
- Prediction is cheaper but has built in errors;
- Measurement is more expensive (however emerging technologies could reduce this cost)



## Rail Temperature Prediction Hypothesis

- Basic Relationship Hypothesised (Existing Method):

$$R_T = a.A_T$$

Existing method approximates  $a = 1.5$  (i.e. rail temperature 50% > ambient temperature)

- Basic Relationship with additional theoretical factors hypothesised:

$$R_T = a.A_T + b.S + c.W + d.H$$

Where  
 $R_T$  = Rail Temperature (°C)  
 $A_T$  = Ambient Temperature (°C)  
 $S$  = Solar Radiation (MJ/m<sup>2</sup>)  
 $W$  = Wind Intensity (Km/h)  
 $H$  = Relative Humidity (%)  
 $a, b, c$  &  $d$  = constants



## Measuring Rail Temperature

- Rail Stress Gauges (with rail temperature measurement capability)**



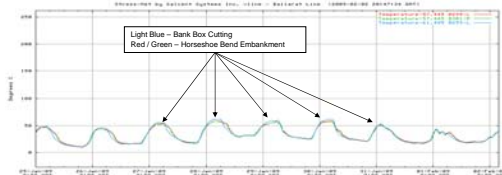
Locations
Lara
Corio
North Shore
Bacchus Marsh
Bank Box
Macedon
Castlemaine
Bendigo
Mystic Park
Warragul

Photo: P. Adams (with permission from V/Line)



## Measuring Rail Temperature

- Example of Rail Stress Gauges Output – January Heat Wave



Date	Max Ambient Temp Ballarat	Max Rail Temp – Cutting Bank Box 1	Max Rail Temp – Cutting Bank Box 2	Max Rail Temp – Embankment Bacchus Marsh
27/01/2009	36.3	54.11 (149%)	52.83 (146%)	55.94 (154%)
28/01/2009	40	58.33 (146%)	58.28 (146%)	61.94 (155%)
29/01/2009	41.4	57.94 (140%)	57.39 (139%)	60 (145%)
30/01/2009	41.1	56.39 (142%)	58.28 (142%)	62.11 (151%)
31/01/2009	39.2	50.67 (129%)	51.67 (132%)	52.94 (135%)

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## Measuring the Weather

- Weather Stations



Locations
Lara
Bacchus Marsh
Bank Box
Macedon
Castlemaine
Bendigo
Mystic Park
Warragul



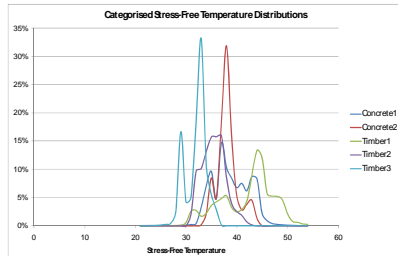
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## Input Variables

- Stress-Free Temperature Distribution
  - Results rationalised into categories to be analysed:



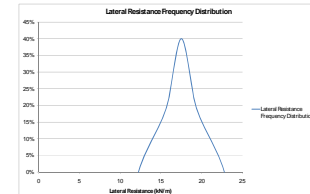
Model	Sleeper	Rail	Curve / Tangent
Concrete 1	Full Depth Concrete	60kg	Tangent
Concrete 2	Full Depth Concrete	60kg	Curve
Timber 1	Timber	47kg	Tangent
Timber 2	Timber	47kg	Curve
Timber 3	Timber	53kg	Curve

**Note 1:** Concrete TRS was sampled on Class 2 lines because the results were discarded due to reliability concerns. For stress distribution on stress sections, all depth concrete distributions have been used for an approximation.

**Note 2:** No samples were taken for timber sleepers on 53kg tangent track. This stress distribution has been used for an approximation.

## Input Variables

- Lateral Resistance Distribution
  - Single Sleeper Push Testing is yet to be undertaken. Hence the following distribution that approximates track with 'average' resistance is utilized.
  - Note that if track has recently undergone maintenance, this value will be significantly less, while track with well compacted ballast could exceed these values.

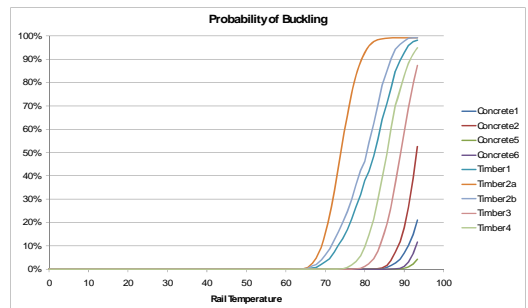


## Input Variables

- The remaining variables are as follows:
  - Sleeper spacing: 685mm base case varied to 500mm, 600mm and 750mm in the sensitivity analysis
  - The track torsional resistance, longitudinal stiffness, and foundation modulus have been assumed based on empirical data.
  - Track alignment has been broken into tangent track and 600m curve radii.
  - Only Vlocity vehicles have been modelled as these have the greatest number of delay minutes attributed to them under WOLO conditions. Other vehicles will be considered in the future.



## Buckling Probability Results



## Buckling Probability Results

- Critical temperature is defined as the temperature where the buckling risk exceeds 1 in 1 million

Model	Track Class	Curve / Tangent	Sleeper	Rail	Fastening	Critical Rail Temp (C <sub>cr</sub> ) °C	Comments
Concrete 1	Class 1	Tangent	Full Depth	60kg	Resilient	81	
Concrete 2	Class 1	600m Curve	Full Depth	60kg	Resilient	79	
Concrete 5	Class 2	Tangent	TRS	47kg	Resilient	85	Full depth SFT data used to approximate
Concrete 6	Class 2	600m Curve	TRS	47kg	Resilient	84	Full depth SFT data used to approximate
Timber 1	Class 2	Tangent	Timber	47kg	Dog / 1 in 4 Anchor	65	
Timber 2a	Class 2	600m Curve	Timber	47kg	Dog / 1 in 4 Anchor	64	
Timber 2b	Class 2	600m Curve	Timber	47kg	Dog / 1 in 4 Anchor	64	Small sample size. Tangent SFT sample used to approximate
Timber 3	Class 2	Tangent	Timber	53kg	Resilient	75	No curve data. Tangent SFT used to approximate
Timber 4	Class 2	600m Curve	Timber	53kg	Resilient	72	

## Buckling Probability Conclusions

- The results of the current network configuration fall into 3 general categories, with rail weight dictating the limits of each category (note this statement will need to be continuously reviewed as the network configuration changes):
  - Concrete sleepers;
  - Timber sleepers with resilient fastenings; and
  - Timber sleepers.
- Considering possible policy options...
  - Drivers cannot differentiate between rail sizes and a human factors analysis suggests that differentiating between fastening type will lead to error
- The only important variable that can be easily differentiated is sleeper type

## Buckling Probability Conclusions

- Thus a new policy would incorporate the most conservative elements present on a line section of the following for both concrete and timber sleepers:

- Rail weight;
- Minimum curve radii;
- Rail temperature prediction.

### e.g.1 Ballarat Line

- Timber and concrete sleepers (although not for much longer!)
- Rail weights include 47kg, 53kg & 60kg
- Minimum curve radii in standard is 600m
- $C_T$  (Concrete) = 79°C
- $C_T$  (Timber) = 64°C
- $R_T = 8.26 + 1.00A_T + 12.89S - 0.02W - 0.02H$  OR  $R_T = 11.37 + 0.98A_T + 13.06S - 0.24W - 0.09H$
- On a sunny day (0.5kN/m<sup>2</sup>), with 5kph wind and low humidity (30%), the ambient air temperature would need to exceed 62°C on concrete sleepers or 47°C on timber sleepers before the risk of buckling would exceed 1 in 1 million



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## Buckling Probability Conclusions

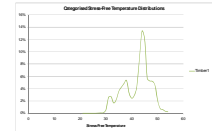
### e.g.2 Kerang to Swan Hill Line

- Timber
- Rail weight 47kg
- Minimum curve radii in standard is 600m
- $C_T$  (Timber) = 64°C
- $R_T = 19.46 + 0.89A_T + 7.35S - 0.33W - 0.14H$

- On a sunny day (0.5kN/m<sup>2</sup>), with 5kph wind and low humidity (30%), the ambient air temperature would need to exceed 42°C on timber sleepers before the risk of buckling would exceed 1 in 1 million

- BUT: the sample used on this section has a skewed stress distribution >38°C

- Assuming that the distribution is skewed by 5°C, the buckling risk would most likely reach 1 in 1 million between 35-39°C.



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## Operational Policy Options

- Blanket Policy:** Single reduction of speed between set times (e.g. 11:00 to 20:00) when weather prediction using relevant formula  $>C_T$  for the specific corridor

Time	$C_T$	Sleeper	Speed
11:00 – 20:00	Line Specific (e.g. 38°C on Geelong line)	Differentiation possible	Would need development to manage $C_T$ risk

- Stepped Blanket Policy with Real Time Monitoring:** Initial reduction of speed between set times (e.g. 11:00 to 20:00) when weather prediction using relevant formula  $>C_T$  for the specific corridor. Real time significant increase in speed restriction after rail temperature exceeds a higher threshold, or removal of restriction after rail temperature  $< C_T$

Time	$C_T$	Sleeper	Speed
11:00 – 20:00	Line Specific (e.g. 38°C on Geelong line)	Differentiation possible	120 kph concrete 80 kph timber
Real Time	Line Specific (e.g. 41°C on Geelong line)	Differentiation possible	60 kph for all



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## Operational Policy Options

- Stepped Real Time Policy:** No set times for reduction of speed. A notification warning that  $C_T$  is expected to be exceeded on a corridor would be posted, then the stepped restriction would be applied in real time. A real time significant increase in speed restriction after rail temperature exceeds a higher threshold, or removal of restriction after rail temperature  $< C_T$

Time	$C_T$	Sleeper	Speed
Real Time	Line Specific (e.g. 38°C on Geelong line)	Differentiation possible	120 kph concrete 80 kph timber
Real Time	Line Specific (e.g. 41°C on Geelong line)	Differentiation possible	60 kph for all



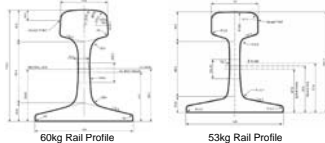
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## Infrastructure Policy Options - Rail

- Future Rail Size Selection

$C_T$ (°C)	47kg	50kg	53kg	60kg
Timber Sleepers with Dog / 1 in 4 Anchors	64	63	65	62

- Do expected future axle loads require 60kg rail or does 60kg rail extend the life of the investment?



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## Infrastructure Policy Options - Sleepers

- Future Sleeper Installation

- Type and Fastening**
  - Difficult to compare full depth concrete with concrete TRS as no STPT available
  - Using vertical force differences only, no significant difference between the two
  - Comparing concrete and resiliently fastened timber,  $C_T$  for concrete is 7 °C higher
  - Comparing concrete and 1 in 4 anchored timber,  $C_T$  for concrete is 20 °C higher
- Sleeper Spacing**

$C_T$ (°C)	500mm	600mm	685mm	750mm
Timber Sleepers with Dog / 1 in 4 Anchors	67	65	64	63
BCR (Maintenance Renewal)	0.5	0.7		0.9
BCR (New Construction)	1.3	1.7		0.2



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## Future Work

- Further SFT Testing
- Lateral Resistance Testing (STPT)
- Remodel to determine key results
  
- Operational Policy Development
  - Policy Finalisation, Consultation and Submission to Safety Regulator
  
- Infrastructure Policy Development
  - Strategic Direction Required for standards and material selection that takes buckling into consideration
    - For maintenance renewals;
    - For new track construction
  - Improve understanding and control of SFT on network



## Thank-You



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