Finite Element Modelling of Railway Turnout Systems

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Finite Element Modelling of Railway Turnout System

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Introduction

• Turnout is a part of the railway where track crosses one another at an angle to divert a train from original track.

• Special sleepers laid on a turnout are called turnout sleepers.

• This sleepers are varying in length and larger in dimension to cope with the complex loading due to crossing of the train.

• This leads to the question of whether a turnout can be justified for flexibility and satisfies both strength and serviceability.
Introduction

• Turnouts require regular maintenance due to adverse and irregular loading.

• Limited information and methodology for turnout sleeper design in current specifications

• Conflicting information in current literatures regarding the location of the critical section.

• Finite Element Analyses enables a detailed visualisation of outputs and a thorough analysis

• Contribute to improving engineering design and methodology
Finite Element Model

• A simplified three-dimensional finite element model consists of longitudinal and transverse brick element has been developed to analyse the behaviour of railway turnout structures.

• The model consist of rails, sleepers pad, sleepers and ballast.
Finite Element Model

In this research the finite element model is restricted to the following parameters:

✓ No irregularities in wheel geometry such as wheel flats and wheel shells;

✓ Concrete sleepers are used for the majority of new track work and spot replacements in Australia;

✓ A specific turnout geometry chosen to be a 250:10.5 tangential turnout, which is a popular turnout design seen in NSW;

✓ Lateral loading will not be considered for elastic analysis;

✓ Friction caused by sleeper/ballast interaction will be neglected when computing vertical deflection, and analysing the stresses within the sleeper.
The modelled turnout will be based upon a standard 250 m, right-hand (RH), tangential turnout design used in NSW.

The turnout has a 1 in 10.5 crossing rate and comprises of 60kg/m rail.

The turnout measures 30.31 m in length.

Concrete sleepers are positioned accordingly to RailCorp standard.
Finite Element Model

(a) 60 kg/m profile

(b) simplified profile

Rail profiles
Finite Element Model

(a) RailCorp standards ESC 250
(b) Simplified nose piece
Crossing profiles
Concrete bearers were modelled as rectangular blocks with dimensions nominated accordingly to RailCorp specifications;

300 mm width, 300 mm depth, and varying lengths between 2.5 m to 7.5 m according to specific turnout design.
Finite Element Model

Boundary Conditions:

**Rail-sleeper (Contact)**
Rail as the master surface and sleeper being the slave surface

**Sleeper-ballast (Tie constraint)**
Sleeper as the master surface and ballast being the slave surface
A train can be represented with a group of 4 axle loads, with 300kN at each axle. The addition of a 360kN load 2m in front of the axle group simulates a coupled locomotive.
Finite Element Model

Stress-Strain Relationship for Concrete according Carreira & Chu (1985)

\[ \sigma_c = \frac{f'_c \gamma \left(\varepsilon_c / \varepsilon'_c\right)}{\gamma - 1 + \left(\varepsilon_c / \varepsilon'_c\right)} \]
Finite Element Model

Stress-Strain Relationship for Different Material according to Loh, et al. (2003)
Finite Element Model

Stress-strain relationship of HS model according to Indraratna and Nimbalkr (2011)
Finite Element Model

Finite Element Model for Turnout at Moving Load
Results and Discussion

Turnout crossing with critical sleepers highlighted (pink)
Results and Discussion

Vertical Displacement According to Moving Load

Vertical Displacement According to Moving Load

- Green: Sleeper 5
- Red: Sleeper 26
- Blue: Sleeper 44
Results and Discussion

Direction of Translation According to Moving Load
Results and Discussion

Shear force envelope for turnout ties TYPE “B” length 2.6-2.8 m

- Sleepers 47 with 51 kN
- Shear force envelope

Shear force envelope for turnout ties TYPE “C” length 2.8-5.2 m

- Sleepers 21 with 17 kN
- Shear force envelope
Results and Discussion

Shear force envelope of sleeper 47 upon wheel impact
Results and Discussion

Bending moment envelope for sleeper 21
Results and Discussion

Bending moment envelope for sleeper 47
Conclusions

The research concluded that:

1. There are three critical sections along the turnout. They are located at the switch point, the nose profile crossing and mid point in between the two points.

2. The nose profile crossing translation is only design for vertical displacement, however, according to the FEM, there are twist and rotation acting on the sleeper.

3. Shear force is within the RailCorp turnouts Shear Envelope.

4. For the switch sleepers, the bending moment is not within the RailCorp SPC 233 Guideline, where there is 55% discrepancy.

5. For nose profile crossing sleepers, the mid point of the sleepers showed a discrepancy of 40% from the RailCorp SPC 233 Guideline.
Conclusions

Design recommendation:

1. The nose profile crossing should consider torsion design.

2. A more thorough analysis including other railway turnout and loading condition should be considered in the sleepers design.

3. The numerical model also needs further calibration and verification using field measurement data.