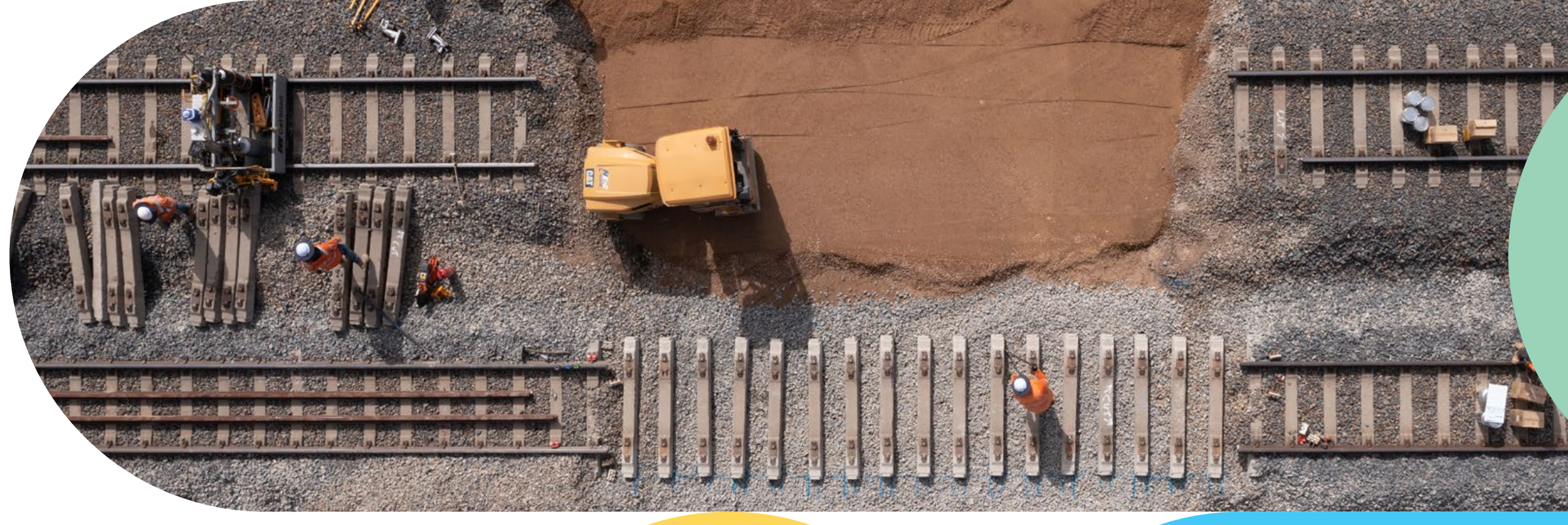


Predictive maintenance forecast using mechanistic formation design

Abstract

Forecasting maintenance intervention is an important aspect of the overall network operation for new and existing rail networks.

Maintenance forecasts can offer an alternative to 'run to failure' strategies and assist significantly with renewal programs. Predicting maintenance can be challenging due to the complexity of rail sleeper, ballast and formation / subgrade behaviour with time. Mechanistic formation design using forecast rail traffic, axle loading and speed can be used to help asset maintenance strategies and better forecast whole-of-life costs.

This poster presents an application of the mechanistic formation design to assist in forecasting maintenance intervention for two cases:

- **Case 1** Section A-A' at a 10m high structure-to-embankment transition (e.g. a bridge abutment); and
- **Case 2** Section B-B' for a 10m high bulk fill embankment adjacent to Case 1.

Case 1 illustrates a typical structure-to-embankment transition where differential settlement impacting vertical alignment dictates the maintenance cycle. Case 2 simulates an embankment further away from the transition zone where settlement requirements may be less stringent. Ballast settlement and degradation is not considered.

Cumulative Plastic Deformation with Mechanistic Formation Design

Train loads and associated imposed stresses are distributed through sleeper, ballast and formation.

One of the functions of the formation layer is to reduce the stress in the subgrade, preventing subgrade failure and excessive deformation caused by repeated train loads. Plastic deformation occurs when the stress placed on a material exceeds its elastic limit, causing it to undergo permanent changes in shape.

An approach proposed by Li et al. (2016), "Railways Geotechnics" and Blanchet and Yang (2019, 2021) to assess plastic deformation. In accordance with these publications, the most common track failures in fine grained soil caused by large repetitive stresses in the formation of subgrade are progressive shear failure and excessive plastic deformation, as illustrated in Figure 1 below.

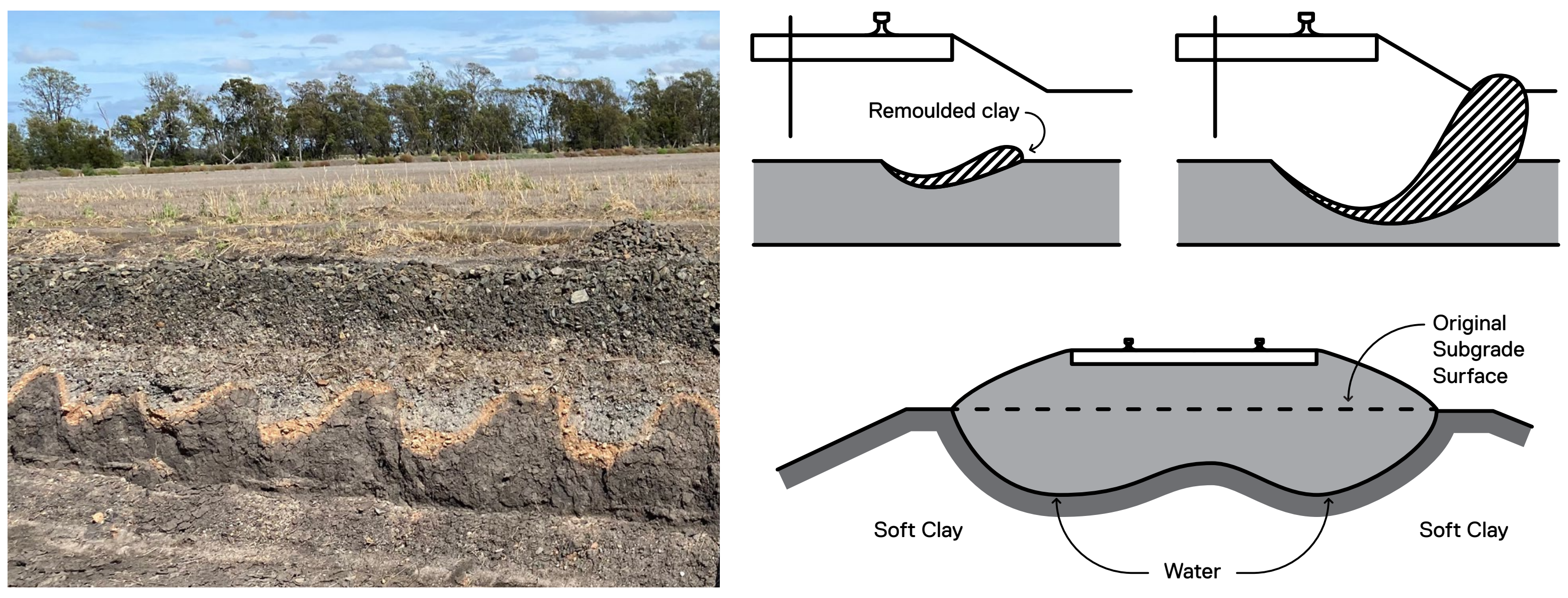


Figure 1 Left: This image presents the cumulative plastic deformation at the subgrade during the removal of the existing track. Right: image was adapted from the literature by Li and Selig (1998).

Blanchet et al 2021 proposed an assessment of stress distribution using three-dimensional finite element modelling of sleeper, ballast formation and subgrade to calculate deformation with time.

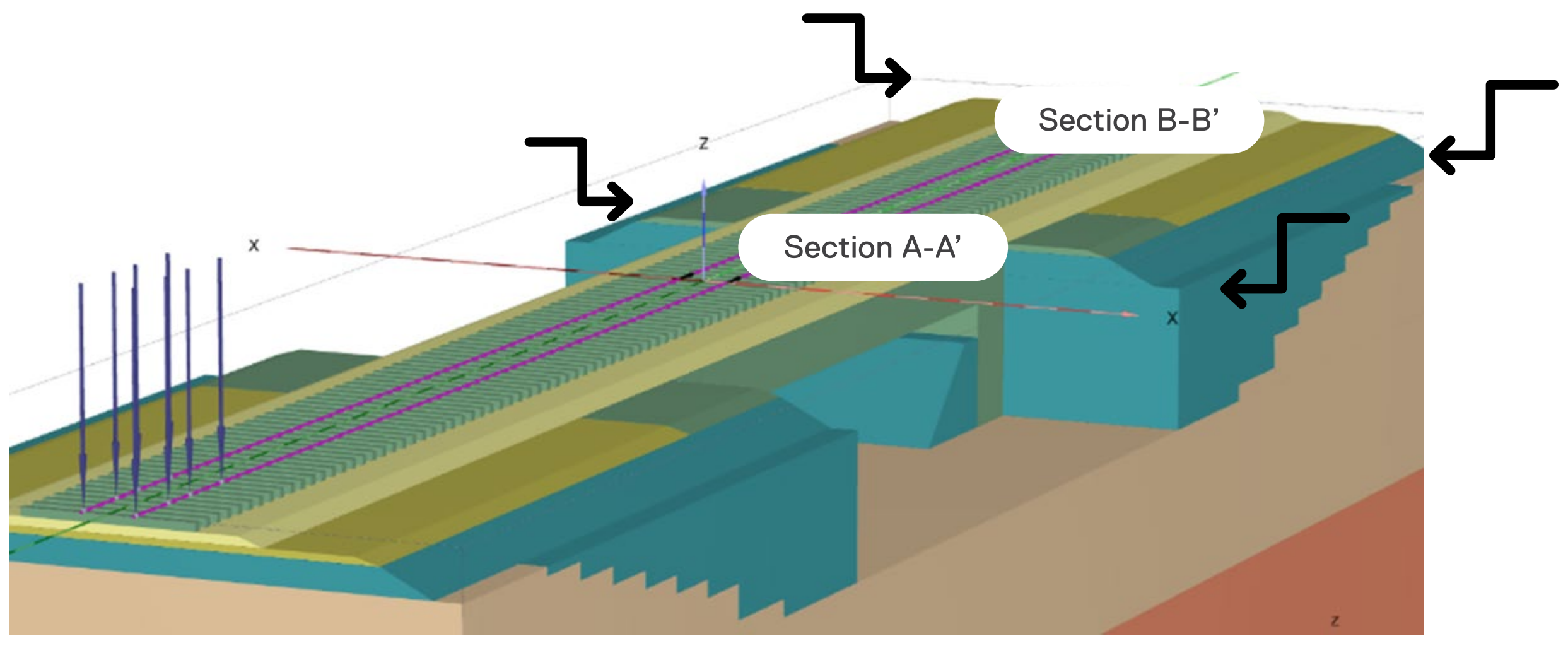


Figure 2 Finite Element Modelling combined with design parameters from Cyclic Triaxial Testing to help predict a maintenance schedule approach.

The plastic strains (εp) and deformation (ρ) can be represented by the following two equations (Li and Selig 1998):

$$\varepsilon_p = \mathrm{a}\left(\frac{\sigma_d}{\sigma_d}\right) N^b$$

$$A = \int_0^T \varepsilon_p \, dt$$

where:

ε_p is the cumulative plastic strain (%),

ρ is cumulative plastic deformation,

N_p is the number of repeated stress cycle applications during the design life (Figure 1),

σ_d is soil deviatoric stress from applied train axial load,

σ_s is soil static compressive strength,

T is the subgrade thickness, and

A, b and m are Li & Selig parameters.

For a given train plan (a typical Train Plan is shown in Figure 3) the equation can be used to predict cumulative plastic deformation.

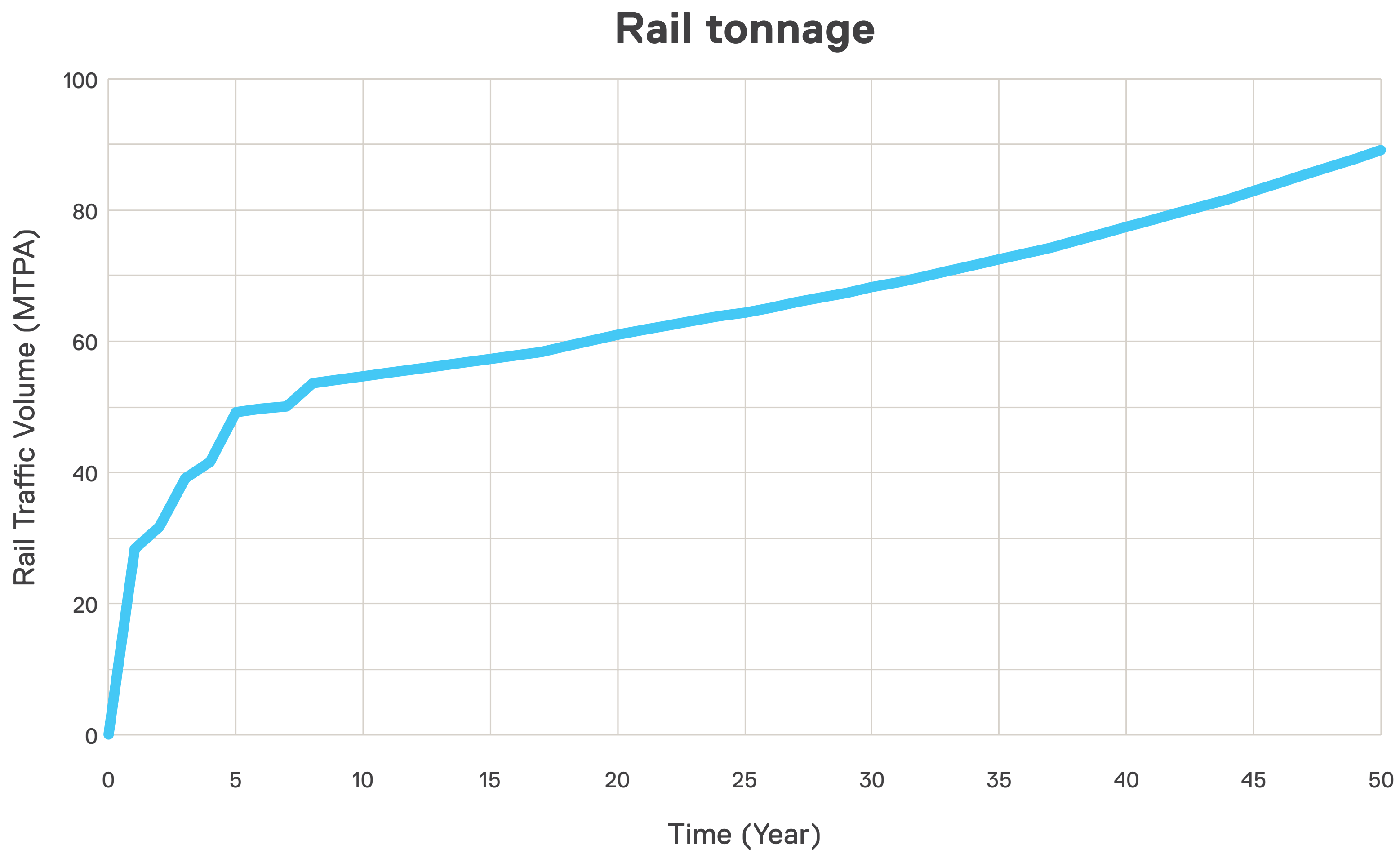
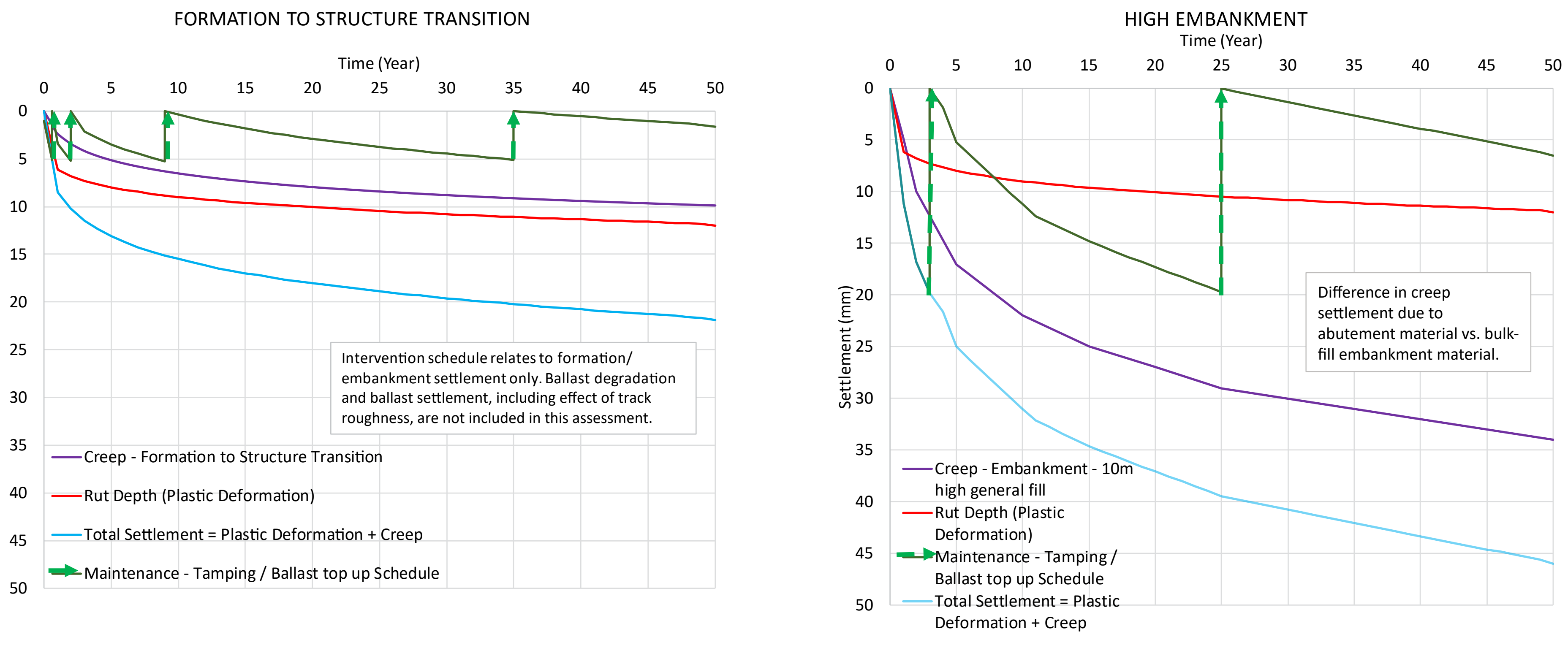


Figure 3 The rolling stock traffic (train traffic per year) was based on rail traffic per year (expressed in Mega Ton per annum).

Case Study: High Embankment and structure-to-embankment transition

Analysis results for Case 1 and Case 2 are presented in Figure 4. This figure illustrates how the method can be implemented to plan intervention and rectification through the design life to maintain compliance with the vertical alignment requirements and mitigate plastic deformation and fill settlement creep. The intervention planning cycle shown is in addition to routine tamping requirement.

Structure-to-embankment transition zones requires additional maintenance intervention and rectification through the design compared with a typical bulk fill embankment of the same height and formation.



Intervention schedule relates to formation/ embankment settlement only. Ballast degradation and ballast settlement, including effect of track roughness, are not included in this assessment.

Difference in creep settlement due to abutement material vs. bulk-fill embankment material.

Figure 4 Intervention planning through design life

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