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Influence of Spatial Variability in Soft Soil and Deep-Mixed-Columns on Long-Term Settlement in Railways

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Abstract

Railway tracks constructed on soft soils are susceptible to accumulated settlement under repeated traffic loading. Although deep mixed columns (DMCs) are used widely as ground improvement method to stabilise soft soils, the spatial variability of both natural and stabilised soils introduces significant uncertainty. This study investigates the influence of spatial variability in soft soils and DMC on the dynamic response and long-term settlement behaviour of railway tracks. An integrated numerical framework combining dynamic vehicle–track–soil interaction (VTSI) modelling with empirical settlement accumulation models is used. A detailed three-dimensional (3D) finite-element (FE) model is used to evaluate the equivalent substructure stiffness as input to a reduced-order two-dimensional model and dynamic response, while a reduced-order iterative model is adopted for long-term settlement prediction. The spatial variability is represented using random field modelling, and its influence is investigated through a fractional factorial design approach. The results show that DMC reinforcement reduces accumulated settlement and increases track stiffness, while increasing spatial variability in the soil and stabilised soil may lead to local differential settlements along the track alignment.

Keywords: Railway settlement, ground improvement, random field, soft soil

1 Introduction

In Sweden, historic railway embankments were commonly constructed using locally available materials with little or no systematic compaction or foundation works. Many of these embankments date back to the time, when construction practices prioritised rapid railway expansion rather than long-term geotechnical performance. Consequently, many railway foundations were built on soft, highly compressible soils that remain susceptible to instability and excessive deformation today. Embankments on soft soils are particularly susceptible to environmental effects such as seasonal moisture variations, which can induce shrink–swell behaviour, cracking, and progressive deterioration of soil strength [1–3].

With increasing train speeds, axle loads, and traffic frequency, the long-term performance of railway infrastructure on soft soils has become a major engineering challenge. Repeated train loading generates cyclic stresses and excess pore water pressures within the subgrade, leading to gradual plastic deformation and settlement accumulation [2, 4, 5]. Differential settlement is especially problematic because it causes track geometry irregularities, increases maintenance demand, reduces passenger comfort, and raises operational costs. Previous studies have shown that soil permeability, drainage conditions, and dynamic VTSI strongly influence settlement development [4].

Several ground improvement techniques have been applied to railway foundations on soft soils, to address these issues. Among them, DMCs have proven to be an effective and sustainable solution for increasing the soil stiffness, improving bearing capacity, and reducing long-term settlement [6]. DMC reinforcement creates composite ground conditions in which loads are shared between the columns and surrounding soft soil, thereby reducing excessive deformation. However, both natural soil deposits and constructed DMC systems exhibit significant spatial variability, due to geological and construction processes. Variability in soft soil properties and DMC stiffness can strongly influence the mechanical behaviour and long-term performance of reinforced railway foundations [7].

In this paper, the influence of spatial variability in stabilised soils on the settlement response of railways is investigated using an integrated numerical framework. The study combines dynamic VTSI analyses with empirical settlement accumulation models to evaluate both short-term dynamic responses and long-term permanent deformation in the ballast and subgrade layers. A detailed 3D FE model is used to compute the stress distribution and equivalent static track stiffness, while, within an iterative framework, a reduced-order 2D FE model integrated with empirical settlement models for the ballast and subgrade is used for long-term settlement prediction; cf. [2]. Spatial variability is incorporated through random-field modelling of both the soft soil and ground improvement [8], including variations in stiffness and column spacing. The results provide insight into how uncertainties in ground improvement impact the magnitude of differential settlement and therefore the long-term railway track performance.

2 Track and vehicle model

In this section, two FE models used for time-domain simulations of vertical dynamic VTSI in a straight railway track are briefly described; see Figure 1. The first model, denoted as Model A, consists of a 2D vehicle model coupled with a detailed 3D track and substructure model including ballast, sub-ballast, fill, and soft clay layers, as presented in [9, 10]. The second model, denoted as Model B, is an equivalent reduced-order 2D model in which the substructure response beneath each sleeper is represented by an equivalent piecewise spring–damper system; further details are provided in [11].

Model B is based on an iterative framework in which a short-term time-domain model of vertical dynamic vehicle–track interaction is integrated with empirical settlement models for long-term ballast and subgrade settlement accumulation [2]. The model accounts for voided sleepers as well as state-dependent ballast and subgrade properties at the sleeper–ballast interface. The empirical settlement models are described in detail in the subsequent section and in [2].

In contrast, Model A is primarily used to obtain a detailed understanding of load transfer and stress distribution within the track substructure and soil layers, as well as to investigate the influence of spatial variability in soil properties and ground improvement measures on the dynamic vehicle–track interaction. Owing to its comprehensive three-dimensional representation of the track foundation system, Model A enables explicit incorporation of ground improvement techniques, such as DMCs installed within the soft clay layers. In both models, the rail is represented using Euler–Bernoulli beam theory and discretised using four beam elements per sleeper bay. In Model A, the sleepers and soil layers are modelled using solid volume elements and elastic continuum layers, respectively. In Model B, the sleepers are represented as rigid masses with a single vertical degree of freedom. The vehicle is modelled as a single-bogie system with four degrees of freedom (DOFs), corresponding to the vertical displacements of the bogie and wheelsets together with the pitch rotation of the bogie. The principal vehicle–track parameters used in the analyses are summarised in Table 1.

In Model B, the sleeper–ballast contact force associated with sleeper i is evaluated at each time step based on the relative sleeper displacement and the accumulated settlement beneath the sleeper. The contact force becomes zero when the calculated sleeper displacement does not exceed the initial gap associated with a voided sleeper. The time history of the sleeper–ballast contact force is calculated for each sleeper, and the maximum values corresponding to each wheel passage are subsequently identified

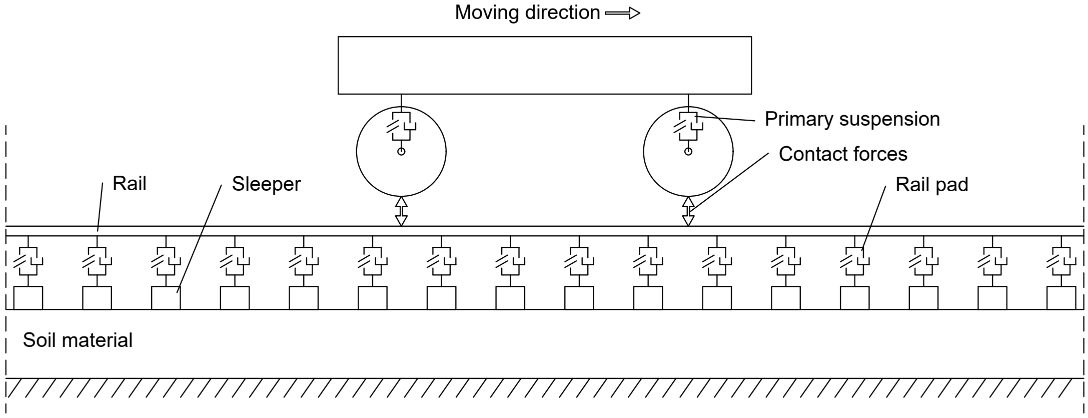


Figure 1: Schematic illustration of Model A including the vehicle–track system and the layered 3D substructure with a soft clay layer.

and used as input to the empirical settlement models.

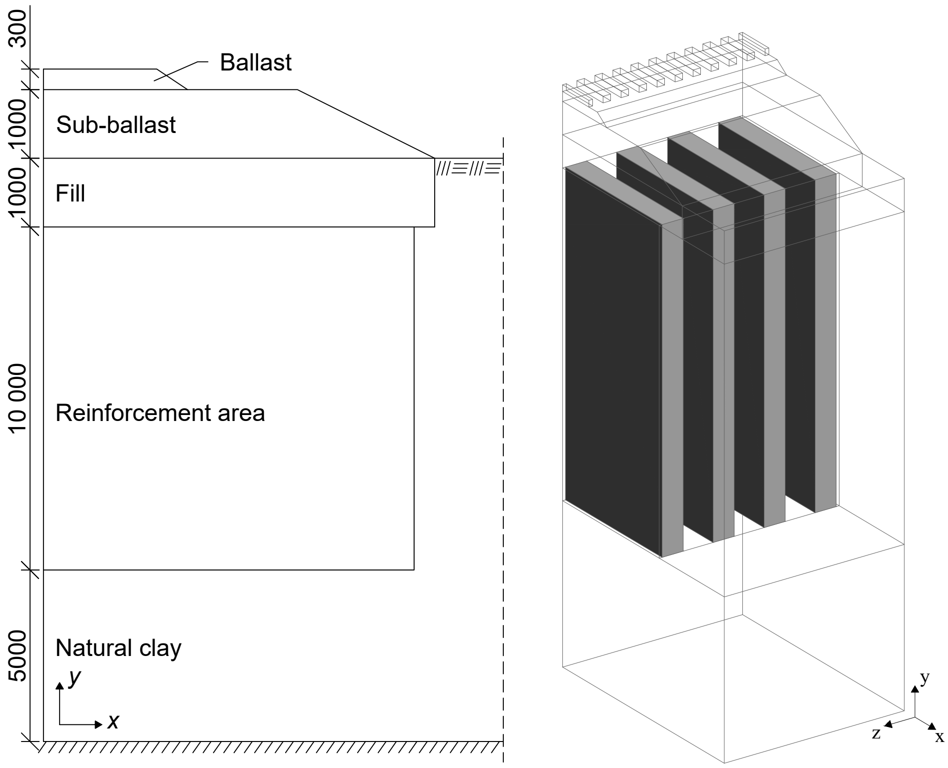


Figure 2: Left: A cross-section of the railway embankment and layered substructure used in Model A. Right: A schematic illustration of the Wall reinforcement configuration with DMC walls installed within the soft clay layer.

The substructure in Model A, the sleepers are assumed to remain fully connected to the substructure throughout the analyses, implying that no loss of contact occurs during the simulations. Based on a mesh convergence study, the model width is selected as 10 m. The total track length is 60 m with a sleeper spacing of 0.6 m. The sleepers and rail seats are numbered using the index i ($i = 1, 2, \ldots, N_{\text{bays}} - 1$), starting from the left side of the track. In both modelling approaches, longitudinal symmetry about the centreline between the two rails is assumed, such that only one half of the vehicle–track system is considered. In Model A, the vertical static stiffness at the sleeper–ballast interface is determined by applying incremental loading–unloading cycles and evaluating the corresponding sleeper displacements. The slope of the resulting force–displacement relationship for each sleeper is subsequently used as input to Model B.

Table 1: Vehicle–track model parameters used in Model A and Model B.

Component	Properties
Ballast	$h = 0.3$ m, $\rho = 1800$ kg/m^3, $\nu = 0.2$, $E = 120$ MPa
Sub-ballast	$h = 1$ m, $\rho = 2200$ kg/m^3, $\nu = 0.3$, $E = 175$ MPa
Fill	$h = 1$ m, $\rho = 2000$ kg/m^3, $\nu = 0.2$, $E = 30$ MPa
Clay	$h = 15$ m, $\rho = 1600$ kg/m^3, $\nu = 0.2$, $E = 5$ MPa
Sleeper	$\rho = 2400$ kg/m^3, $E = 30$ GPa, $\nu = 0.2$, $m_s = 150$ kg
Rail	$\rho = 7850$ kg/m^3, $A_c = 7.67 \times 10^{-3}$ m^2, $E = 210$ GPa, $\nu = 0.3$
Rail pad	$k_{r/s} = 120$ kN/mm, $c_{r/s} = 25$ kNs/m
Bogie	$M_b = 15300$ kg, $J_b = 1.476 \times 10^3$ kgm^2
Wheelset	$M_w = 900$ kg, $\Delta_w = 2.5$ m
Primary suspension	$k_p = 1200$ kN/m, $c_p = 4$ kNs/m
Train loading	$v = 200$ km/h, $P_a = 17.1$ tonnes

h: thickness; ρ: density; ν: Poisson's ratio; E: elastic modulus; A_c: cross-sectional area; m_s: half sleeper mass; k: stiffness; c: damping coefficient; M: mass; J: mass moment of inertia; Δ_w: wheel spacing; v: train speed; P_a: axle load.

3 Settlement model

Track settlement is highly dependent on local ground conditions and may originate within both the granular layers (ballast and sub-ballast) and the underlying subgrade (clay stabilised with DCM). In tracks constructed on deep soft soils, the long-term settlement is primarily governed by consolidation and creep in the subgrade. Conversely, when the ballast rests on a properly dimensioned foundation, a considerable portion of the accumulated settlement occurs within the ballast layer, characterised by non-linear behaviour under repeated loading. The permanent deformation within the granular and subgrade layers is calculated using two empirical settlement models, which are described in the following sections and presented in more detail in [2, 11]. The settlement increment in the ballast is calculated for each sleeper and iteration step as a function of the maximum sleeper–ballast contact force using a visco-plastic threshold model:

$$\delta_{i,j} = \sum_{n=1}^{N_{\text{w}}} \left[\sum_{k=1}^{N_{\text{k}}} \alpha_k \left(\frac{\max(F_{\text{s/b},i})_n - F_{\text{th},i}}{F_0} \right)^{\beta_k} \right] \tag{1}$$

where $\delta_{i,j}$ is the incremental ballast settlement beneath sleeper i at iteration step j, $F_{\text{s/b},i}$ is the maximum sleeper–ballast contact force for sleeper i due to a wheel passage, and $F_{\text{th},i}$ is the threshold load controlling the onset of permanent deformation. The accumulated ballast settlement beneath sleeper i after iteration n_s is calculated as:

$$\Delta_{\text{ballast},i}(n_s) = \sum_{j=1}^{n_s} \delta_{i,j} \tag{2}$$

To account for ballast compaction and hardening, the threshold load evolves according to:

$$F_{th,i}(\Delta_{\text{ballast},i}) = F_{th,\infty} - (F_{th,\infty} - F_{th,0})e^{-\gamma\Delta_{\text{ballast},i}} \tag{3}$$

where $F_{\text{th},0}$ and $F_{\text{th},\infty}$ denote the initial and long-term threshold loads, respectively, while γ = 0.11 is a ballast hardening parameter. In the present study, the model parameters are selected as $F_{\text{th},0} = 25$ kN, $F_{\text{th},\infty} = 50$ kN, $F_0 = 1$ kN, $N_\text{k} = 1$, and $N_\text{w} = 2$. Furthermore, $\alpha_k = 0.0002$ mm per 1000 load cycles and $\beta_k = 2.8$. The subgrade settlement is evaluated using the Li and Selig model [12]. The cumulative plastic strain in soil layer k after N load cycles (wheel passages) is expressed as:

$$\varepsilon_{p,k} = a\left(\frac{\sigma_{d,k}}{\sigma_{s,k}}\right)^m N^b \tag{4}$$

where a, b, and m are empirical soil parameters, while $\sigma_{d,k}$ and $\sigma_{s,k}$ denote the deviatoric stress and compressive strength of soil layer k, respectively. The ranges for parameres a, b, and m adopted in the present study are collected from [2]. The total subgrade settlement is obtained from:

$$\Delta_{\text{subgrade}} = \sum_{k=1}^{K} \varepsilon_{p,k} h_k \tag{5}$$

where h_k is thickness of each layer. the total settlement beneath each sleeper is computed as:

$$\Delta_{\text{total},i} = \Delta_{\text{ballast},i} + \Delta_{\text{subgrade},i} \tag{6}$$

4 Deep–mixed (DM) columns in the soft soil layer

Dry Deep Mixing (DDM) is a widely used ground improvement technique in the Nordic contries in which binders, such as lime and cement, are mechanically mixed with the soft soil, particularly clay, to form DMCs. They are typically installed as cylindrical columns arranged in square or triangular patterns beneath the track. Depending on the depth of the soil deposit, the columns may act as floating columns primarily transferring load through shaft resistance or as end-bearing columns transferring load to a stiffer underlying layer. In Nordic countries, column diameters generally range between 0.5 and 0.8 m, with installation depths commonly between 7.5 and 15 m [7, 13].

For an efficient numerical analysis, in this study the DMC-reinforced soil is represented as discrete walls with a certain spacing along the track where the properties are calculated using a volume-averaging approach. The equivalent Young's modulus is determined using a homogenisation principle, in which the contributions from the columns and the surrounding soil are weighted according to their respective volume fractions. The soil volume fraction, Ω_{soil}, is equal to $1 - \Omega_{\text{columns}}$. It is acknowledged that the differences in mass are not considered in this study. The equivalent Young's modulus for the wall approach is expressed as

$$E_{\text{wall}} = \Omega_{\text{columns}} \, E_{\text{columns}} + \Omega_{\text{soil}} \, E_{\text{soil}} \tag{7}$$

In this approach, the averaging is performed locally for each wall segment. The volume-averaged stiffness was calculated for a reinforcement zone with a height of 10 m and a width of 4.6 m. The individual columns were assumed to have square cross-sections with side lengths of 0.7 m, installed in a square pattern with a centre-to-centre spacing of 1.7 m.

Despite their effectiveness, the mechanical properties of DMCs exhibit considerable spatial variability due to heterogeneity in the natural soil and the uncertainties introduced by the mixing process. Variations in water content, soil composition, binder distribution, and installation quality can lead to significant differences in stiffness and strength between adjacent columns [7]. Consequently, the influence of vertical and horizontal stiffness variations, alongside the horizontal spacing of the DMCs, is investigated in [14]. The present work evaluates the influence of soft soil improvement on the long-term differential settlement of a railway track. The input parameters for this DMC study are adopted from the experimental and numerical works in [7].

5 Results and discussion

This section presents the short-term responses and predictions of long-term differential settlement obtained using the integrated VTSI and empirical settlement models. A comparative study of both the short- and long-term responses for a railway embankment with soft soil layers (reference case) and a DMC-reinforced foundation modelled as walls (wall case) is presented.

5.1 Track receptance

A vertical harmonic load within the frequency range of 0–1500 Hz is applied at the mid rail seat (rail seat 51) to minimise boundary effects in the response. The receptance, defined as the ratio between displacement and input force, is evaluated at the same DOF as the excitation. Figure 3 presents the direct receptance for both the reference and wall cases. Two resonance frequencies and one anti-resonance frequency can be identified. The first resonance frequency, occurring at approximately 62 Hz in the reference case and 77 Hz in the wall case, corresponds to in-phase motion of the rail and sleepers, whereas the second resonance frequency around 320 Hz is associated with out-of-phase motion between the rail and sleepers. The anti-resonance frequency near 1344 Hz corresponds to the so-called pinned–pinned mode, where the rail vibrates with a wavelength equal to the spacing between two rail seats. Furthermore, for the reinforced cases, the first resonance frequency shifts towards higher frequencies, due to the increased stiffness of the supporting structure. This indicates that wave propagation in the stiffer region also occurs at higher speeds, since the stiffness and wave speed in the subgrade are directly related.

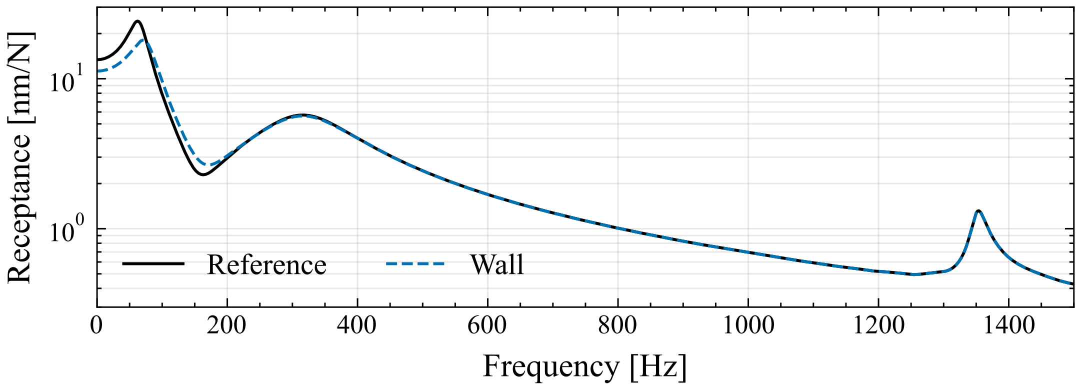


Figure 3: Magnitude of the direct recpetance calculated for the 2D model. The excitation and the response are calcutlated at the middle rail seat of the model.

5.2 Vertical static track stiffness at the rail level

Based on the stiffness matrices of the track model for the investigated scenarios, the vertical static track stiffness at rail level is evaluated, as shown in Figure 4. The periodic pattern observed is caused by the discrete rail supports, where each peak corresponds to a rail seat location. The calculated stiffness indicates that the wall configuration exhibits higher vertical static track stiffness compared with the reference scenario. Furthermore, the stiffness remains nearly uniform along all rail seat positions for each case, indicating consistent load transfer along the track alignment.

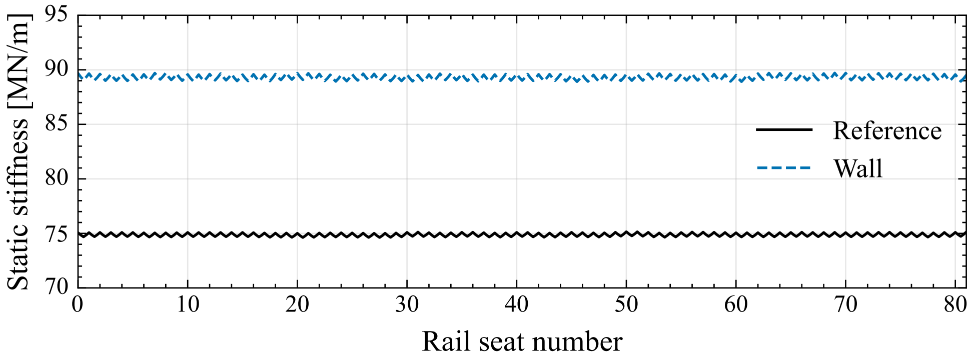


Figure 4: Vertical static track stiffness at rail level for the investigated scenarios.

5.3 Vertical wheel–rail and maximum sleeper–ballast contact force

The vertical wheel–rail contact force and the sleeper–ballast contact force after the first vehicle passage are presented for the reference and wall cases in Figure 5. Figure 5a shows the wheel–rail contact force response, which exhibits a periodic oscillatory behaviour associated with the discrete rail supports and the dynamic interaction between the vehicle and the track system. Compared with the reference case, the wall case shows slightly higher contact force amplitudes due to the stiffer support conditions introduced by the improved substructure. Figure 5b presents the sleeper–ballast contact force. The reinforced case exhibits higher sleeper–ballast contact forces compared with the reference scenario, which is consistent with the increased dynamic amplification observed in the wheel–rail contact force response. These contact force levels are subsequently used as input to the empirical settlement models for predicting long-term settlements.

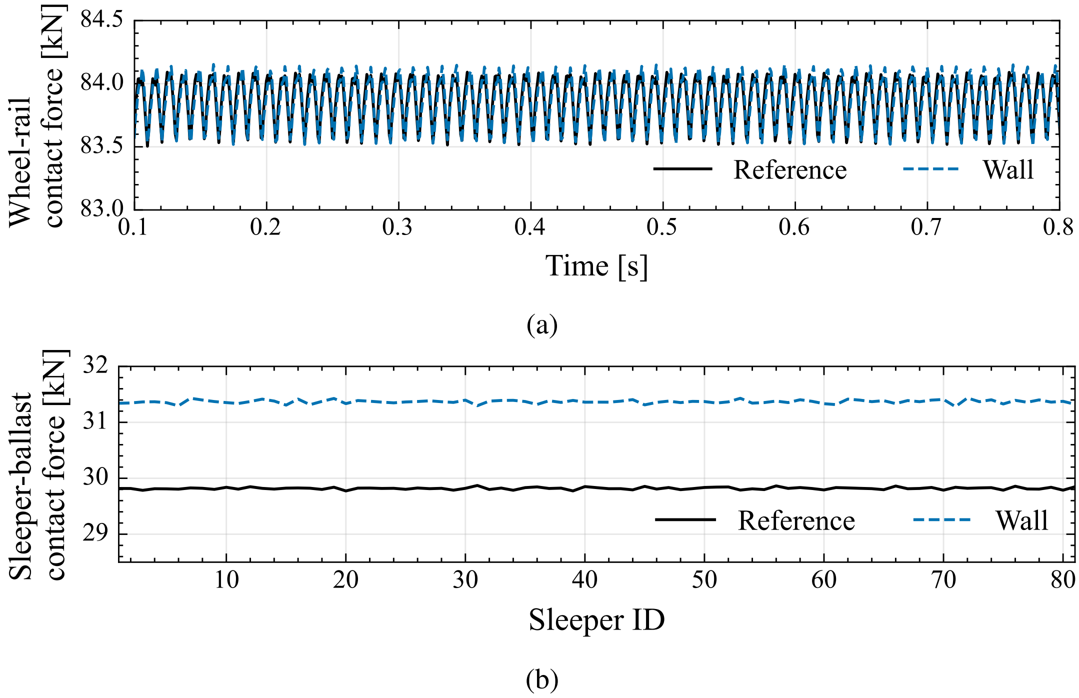


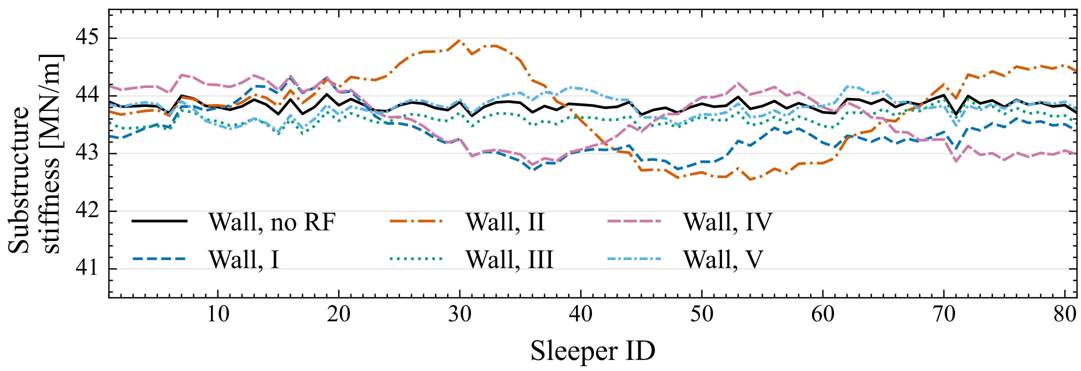
Figure 5: Dynamic contact force responses for the reference and wall cases after the first vehicle passage: (a) wheel–rail contact force response and (b) sleeper–ballast contact force.

5.4 The influence of spatial variability in DMCs on vertical sleeper displacement

The influence of spatial variability in the reinforcement properties of the DMC (elastic modulus) on the vertical static track stiffness at the sleeper–ballast interface along the track alignment is investigated. The spatial variability is modelled using random fields, where different ranges of the scale of fluctuation are applied to the mean elastic modulus. The values for the vertical, longitudinal, and transversal scale of fluctuation of the DMC column stiffness are adopted from those experimentally determined in [7] and are summarised in Table 2. Figure 6 presents the equivalent substructure stiffness at the sleeper–ballast interface for the wall base scenario together with the five random field realisations. Compared with the deterministic base scenario, the random field cases exhibit larger local stiffness variations along the track alignment while maintaining similar average stiffness levels. Random Field II shows the highest variability due to the combined influence of large vertical and longitudinal fluctuation scales, which produce stronger spatial correlation in the DMC stiffness distribution. In contrast, Random Fields III and V exhibit smoother stiffness distributions associated with smaller fluctuation scales and shorter correlation lengths. Overall, the longitudinal fluctuation scale has the greatest influence on the variation of equivalent track stiffness along the railway alignment.

Table 2: Horizontal and vertical scales of fluctuations of DMCs, collected from Wong et al. [7].

	Ave	Min	Max	I	II	III	IV	V
Vertical	1.4	0.4	3.5	Ave	Max	Min	Min	Max
Longitudinal and transversal	1.6	0.4	4.3	Ave	Max	Min	Max	Min

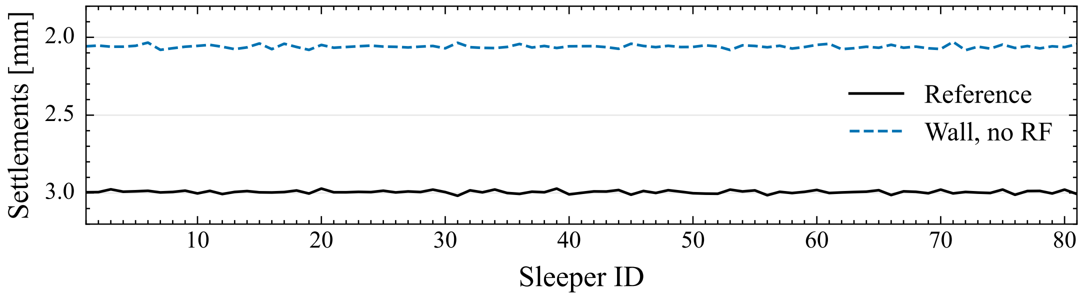


	No RF	I	II	III	IV	V
CV (%)	0.19	0.91	1.61	0.28	1.13	0.40
Range (MN/m)	0.37	1.61	2.42	0.60	1.56	0.78

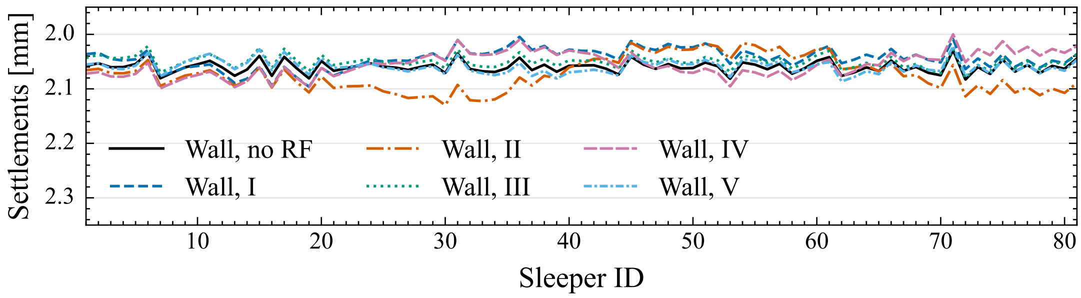
Figure 6: Equivalent substructure stiffness for the base scenario and five realisations of the random field at each sleeper position in the 3D FE model. The embedded table summarises the calculated CV and stiffness range for each random field scenario.

5.5 Long-term settlement

In this section, the predicted long-term settlements for the investigated scenarios are evaluated. Figure 7 presents the estimated settlement accumulation for the Reference and Wall base scenarios together with the corresponding random field realisations for the Wall configuration. Figure 7a compares the base scenarios without random field effects, whereas Figure 7b illustrates the Wall scenarios considering different random field realisations. The results show that the Wall configuration generally exhibits lower accumulated settlements compared with the Reference case, demonstrating the beneficial effect of the DMC reinforcement on the long-term track response. The random field realisations follow trends similar to the deterministic Wall scenario, although local settlement fluctuations are observed along the sleeper positions due to the spatial variability of the equivalent substructure stiffness. Cases with larger stiffness variations also exhibit slightly higher differential settlements. Nevertheless, the overall settlement response remains relatively uniform, indicating that the reinforced Wall configuration effectively mitigates excessive subgrade deformation and improves long-term track performance.



(a)



(b)

Figure 7: Predicted long-term settlements for the investigated scenarios: (a) base scenarios without random field effects and (b) Wall scenarios with different random field realisations of the DMC stiffness distribution.

5.6 Sensitivity analysis of long-term settlement variability

The influence of the parameters of the random field on the accumulated long-term settlements is investigated for the Wall configuration using a 2^{4-1}_{IV} fractional factorial design. The design was selected as $I = ABCD$, where θ_y was assigned to factor D.

In the factorial design, θ_{xz} represents the longitudinal scale of fluctuation of the DMC stiffness properties along the track direction. Larger values of θ_{xz} correspond to longer spatial correlation lengths and therefore smoother stiffness transitions between adjacent reinforcement elements. The parameter CV_{DMC} defines the coefficient of variation of the DMC stiffness and controls the magnitude of the spatial stiffness variability. Increasing CV_{DMC} leads to larger contrasts between stiff and soft regions within the reinforced layer. The parameter ctc_z denotes the centre-to-centre spacing between adjacent DMC walls, where larger spacing reduces the reinforcement density and increases the sensitivity of the track response to local stiffness variations. Finally, θ_y represents the vertical scale of fluctuation of the DMC stiffness field.

The factorial design and the corresponding statistical metrics for the accumulated long-term settlements are summarised in Tables 3 and 4. The results show that the wall spacing parameter ctc_z strongly influences the differential settlement behaviour. Simulations with larger ctc_z values generally exhibit larger local settlement fluctuations, indicating that increased spacing between reinforcement walls reduces the uniformity of the track support conditions. The influence of CV_{DMC} is especially evident in Simulations 4 and 7, where larger settlement variability is observed due to the increased contrast in local support stiffness. Similarly, larger values of θ_{xz} produce smoother and more spatially correlated settlement patterns, whereas smaller values result in more rapidly varying local settlements along the track alignment.

The statistical indicators further support these observations. Simulations 4, 6, and 7 exhibit comparatively larger coefficients of variation, indicating more pronounced differential settlement behaviour. In contrast, Simulations 1, 3, and 5 show smoother settlement distributions due to smaller stiffness variability and denser reinforcement configurations. The corresponding MSSD/s^2 values further confirm these trends, where larger values indicate stronger local settlement variations between adjacent sleeper positions. The adopted 2^{4-1}_{IV} fractional factorial design is of resolution IV, meaning that the main effects can be interpreted independently assuming negligible higher-order interactions. Future work should also investigate the influence of additional parameters, such as the depth of the soft soil layer, on the long-term settlement behaviour.

Table 3: Parameter levels used in the factorial design.

Factor	Parameter	Unit	Levels		Range (%)
			$-$	$+$	
A	θ_{xz}	m	2.25	3.75	50
B	CV_{DMC}	[-]	0.20	0.30	40
C	ctc_z	m	1.36	2.04	40
D	θ_y	m	1.50	2.50	50

Table 4: Fractional factorial design matrix and statistical metrics for the accumulated long-term settlements of the Wall configuration.

Run	θ_{xz}	CV_{DMC}	ctc_z	θ_y	CV (%)	λ (m)	MSSD/s^2
1	$-$	$-$	$-$	$-$	1.07	36.43	0.44
2	$-$	$-$	$+$	$+$	0.81	0.6	2.40
3	$-$	$+$	$-$	$+$	0.75	13.76	0.91
4	$-$	$+$	$+$	$-$	1.60	36.90	0.64
5	$+$	$-$	$-$	$+$	0.66	20.89	1.20
6	$+$	$-$	$+$	$-$	1.36	42.29	0.85
7	$+$	$+$	$-$	$-$	2.00	42.45	0.13
8	$+$	$+$	$+$	$+$	0.96	0.6	1.75

6 Concluding remarks

This study investigated the influence of spatial variability in DMC-reinforced soft soils on the emerging dynamic response and long-term settlement behaviour of a ballasted railway track. The study combines detailed 3D FE modelling with a reduced-order 2D FE model integrated with empirical settlement models, enabling evaluation of both short-term dynamic behaviour and long-term differential settlement accumulation. The results showed that DMC reinforcement increases the vertical track stiffness and reduces the accumulated long-term settlements compared to the reference soft-soil case. The reinforced configurations also produced more uniform track support conditions, demonstrating the effectiveness of DMCs in improving railway performance on foundations in soft soils.

The random field analyses demonstrated that spatial variability in the reinforced ground introduces local variations in both track stiffness and settlement response along the track alignment. In particular, increased spacing between adjacent reinforcement walls and larger variability in the DMC stiffness properties resulted in more pronounced differential settlements. Furthermore, larger horizontal scales of fluctuation produced smoother and more spatially correlated settlement patterns, whereas shorter correlation lengths generated more rapidly varying local settlements between adjacent sleeper positions.

Overall, the study highlights the importance of accounting for spatial variability in railway foundations when evaluating long-term track performance on soft soils. Although the reinforced configurations generally improved the long-term track behaviour, local stiffness variations may still contribute to differential settlement accumulation and track irregularities over time. Future work should investigate the influence of additional properties, such as the depth of the soft soil layer, groundwater conditions, and variability in the natural soil deposits, on the long-term settlement behaviour and maintenance requirements of railway infrastructure.

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