Review of “**Ground Vibrations from High-Speed Railways: Prediction and mitigation**”, Victor V. Krylov (Ed), ICE Publishing, London (2019) ISBN: 9780727763792

As the global demand for transport continues to increase, high-speed railways have become a potentially carbon-zero alternative to air transport for domestic and continental travel. However, the price of the increased in-service speed of the high-speed trains, compared to conventional railways, is the generation of a number of additional engineering challenges regarding operational safety and increased levels of environmental vibration and noise. Several of these challenges are associated with the ground vibration performance of the track and its subgrade, so in the last two decades there was a clear attractiveness to study it and propose improvements for the prediction and mitigation of the hindrances due to the high-speed train passages.

‘*Ground Vibrations from High-Speed Railways: Prediction and mitigation*’ aims to present in one volume the results of recent international research on the generation and propagation of ground vibrations from high-speed trains and to discuss potential mitigation of their impact. The book presents methods of analysis and established computational models along with several examples of predicted and measured results that can be used as tools for solving vibration issues on operational high-speed lines, or for predicting the railway performance in the design stage. Moreover, it contains fundamental knowledge on the current status of the problem that can be used as a general reference for further improvements and research.

There are 12 independent chapters in the book written by 23 leading international experts based in 10 different countries. These chapters include the results of recent works of the authors that have been published in the peer-reviewed literature. Since high-speed trains are mainly run on surface railways, most of the cases covered in the book describe tracks at grade. Inevitably, since the chapters have been written independently, there are no cross-references or uniform nomenclature and some quantities are represented with different symbols between chapters. The reader may also find a few introductory sections that overlap between chapters; nonetheless, this allows reading each chapter independently. The text is pitched largely at an advanced level and the reader should have a university background in engineering, physics or applied mathematics.

Despite the diversity of authorship, the writing style is reasonably consistent and the English is to a good standard. All of the illustrations are in grayscale, which in some cases may impede the understanding of the graphs. Each chapter contains relevant references that include published papers of the authors and in most cases include more comprehensive literature references beyond the work of the authors. An eight-page glossary is included, which covers many of the relevant terms.

The **first chapter** ‘Dynamic track-ground behaviour on high speed rail lines’, by Connolly et al. is focused on describing the correlation between train speed and track-subgrade deformation. The authors briefly summarize many of the available methods that can be used to predict the deformation and derive the critical velocity where the deformation reaches its maximum. A number of ground conditions are introduced and comprehensive graphs explain the relation between the soil parameters and the critical velocity. Altogether, this is a useful and well-written introduction and scoping study on the topic of critical velocity.

**Chapter 2**, ‘Dynamic track-ground behaviour on high-speed rail lines’ by Auersch studies in depth the soil-track interaction and the propagation of ground vibration for different types of layered soils and train speeds. The presentation of the theoretical background describes adequately the semi-analytical derivation and coupling of the dynamic stiffness matrices of the ground, the track and the train subsystems. The analysis is performed in the combined wavenumber and frequency domains, and knowledge of some basic concepts such as the wavenumber space, the compliance and the boundary element (BE) method is assumed. Ground velocity results predicted by the theoretical models developed by the author are presented for a number of cases and some of these cases are compared with measured data. The predictions show consistency with the measured results, however, all the comparisons are from transfer function hammer tests and do not contain information about ground vibration from high-speed trains. A collection of ground vibration measurements from train passages with conventional and high speeds is presented in the chapter without substantial discussion. The chapter finishes with an introduction to the concept of vibration mitigation measures at the track by using soft rail pads, under-sleeper pads or ballast mats and some theoretical results are presented.

**Chapter 3**, 'Computational tools for predicting ground vibration from railways' by Talbot et al. introduces five recently established toolboxes that can be used to predict ground vibration from surface and underground railways. The chapter is well written and includes demonstration of the operation of the models. The main contribution here lies in the fact that the authors not only present these five specific models, but also communicate important practical considerations that provide guidance at an engineering level for the selection of prediction tools from those available in the field.

**Chapter 4**, 'Semi-analytical approaches to vibrations induced by moving loads with a focus on the critical velocity and instability of the moving object' by Dimitrovová presents the theory of train-track interaction paying special attention to instabilities of the high-speed moving system (train). The author considers different types of elastic and viscoelastic foundations for modelling the combined track and supporting ground system and simple train models considering only the moving loads and models with only one or two degrees of freedom. The presented results are reproducible and although the one-dimensional simplified foundation model used to represent the track-subgrade does not allow delving into the physics of ground vibration and its propagation, it captures the necessary features for studying the instability of the train-track or the wheelset-track systems that may be caused due to the increased train speed. Such results are deemed as important for the preliminary design of railway tracks to avoid excessive vibrations and prevent derailment of the high-speed rolling stock.

**Chapters 5**, 'Ground vibrations from high-speed non-ballasted railways: numerical prediction and field experiment' by Zhai and Yang and **Chapter 6**, 'Predicting high-speed railway vibration using time-domain numerical engineering approaches' by Kouroussis present results from numerical studies on high-speed railway vibration using two established time-domain prediction approaches. In both approaches, a two-stage framework is used that allows the train, the track and the ground to be modelled in high detail. The ground is modelled using finite element (FE) analysis; however, the track and the soil are not strongly coupled; a quite simplified track foundation model used in the first stage to estimate the track-soil interaction forces, which are used in the second stage for the calculation of the ground vibration at the far field using the FE model. The concepts of the track resonances are introduced and the issue of the critical velocity is considered in the presented results. It is not explained if the track-soil coupling assumptions will affect the accuracy of the methods. Chapter 5 includes comparison of the numerical predictions with field experiments but unfortunately, there is no conclusions section to draw things together.

**Chapter 7**, 'The 2.5-dimensional approach to modelling ground vibrations from high-speed railways' by Sheng, presents one of the most prominent numerical methodologies in the field of ground vibration and railway acoustics. The author considers both the 2.5D FE and BE methods for both invariant and periodic geometry along the railway track and communicates important knowledge regarding issues that arise in the numerical implementation of the methods. Additionally, it is explained how different modelling domains (BE-BE and FE-BE) can be coupled and how to include the multibody train vehicles through the wheel-rail interaction. For the latter, the concept of the wheel-rail roughness is introduced as one of the main contributors to the generation of ground vibration and the relationship between the statistics of the roughness with the levels of vibration at the far field is revealed. It is then briefly demonstrated how the methodology can be applied to different practical problems involving high-speed trains. Overall, the chapter holds the coherence of a textbook showing a high level of dissemination and reproducibility.

**Chapter 8**, ‘Hybrid prediction methods for vibrations from high-speed railways’ by Kuo et al. reviews the semi-empirical models that combine field measurements and numerical methods and offer greater flexibility and robustness than a single modelling method. Reflecting the international standards for the assessment of vibration in buildings near railway tracks the authors consider the separation of source excitation, propagation path and building response terms. The well-presented hybrid model framework and the two practical examples, for a newly-built railway in an urban environment and for a newly-constructed building near an existing railway, can be used as guidance for practising engineers to assess reliably and with reduced cost the vibration hindrance in buildings at the design stage.

**Chapter 9**, ‘Benchmark solutions for vibrations from a moving source in a tunnel in a half-space’ by Boström and Yuan echoes one of the models presented in Chapter 3 and the methodology presented in Chapter 7. The authors present an efficient semi-analytical method that can be used to determine the vibrations from an underground railway and in a circular tunnel. Although the proposed methodology and the results presented here do not include the train vehicles and the wheel-rail interaction model, they can be used for the characterization of the vibration propagation from the tunnel to the surrounding soil. Such models are widely used for metro railways; however, they can also be applied for studies that involve underground sections of high-speed railways or the recently proposed Hyperloop vehicles. It is the only chapter in the book that directly addresses a buried tunnel system and also considers the effect of water saturation of the soil.

In **Chapter 10**, ‘Scoping assessment of ground and building vibrations due to railway traffic’ by Galvin et al., the concepts of the excitation, propagation path and building immission are revisited echoing Chapter 8. Nevertheless, the prediction model proposed here is purely numerical and does not rely on measured information. In order to reduce significantly the computational effort for solving the fully coupled train-track-soil-building model, the propagation term is reduced using a neural network identification approach and major simplifications are implied for the soil layering and the track-soil and soil-building coupling mechanisms. The modelling technique is well explained and the chapter is illustrated with examples of parametric studies. The cases presented do not include predictions for high-speed trains, although there is nothing to imply that the model cannot be used for increased train speeds. It is concluded that good prediction performance can be achieved and that the proposed modelling technique can be used to predict building vibration at the early design stage.

**Chapter 11**, ‘Finite-element approach to train induced vibrations of pile supported embankments’ by Thach presents a study on a specific mitigation technique that can be employed to solve issues related to soft soil and critical velocity in high-speed railways. The installation of piles to reinforce the railway supporting subgrade is indeed a potential and prominent solution for these problems. The results presented in this chapter are useful for the calibration and quantification of the performance of such measures. Unfortunately, as the study concentrates on a specific application by using established FE methods, it contains little physical insight of value regarding the fundamentals of ground vibration.

The **last chapter**, ‘Stochastically rough surfaces as seismic barriers against railway-induced ground vibrations’ by Krylov proposes a rather novel mitigation measure that differs from those previously discussed in the book. The measure, that aims to disrupt the vibration propagation at the ground surface for the cases of critical and super-critical train velocities, proposes the construction of scattered shallow troughs and soil hummocks to create an artificial random unevenness of the soil surface adjacent to the potentially problematic high-speed sites. The mathematical background, that is based on the theoretical increase of the vibration attenuation coefficient of the induced ground surface waves, is explained and some preliminary results are presented. The effectiveness of the proposed measure compared to typical deep trenches that can be used for the disruption of the vibration propagation path is briefly discussed. However, it is not shown if the proposed measure can reduce the effects of the critical velocity at the railway track where the operational safety and the track degradation are at stake.

Overall, the book covers an important area in the field of railway engineering. It is a timely publication describing the up to date progress in the area. As a volume that is formed of many separate contributions it lacks the continuity of a textbook. In terms of mitigation measures, the coverage is not consistent and not very comprehensive and it is unfortunate that high-speed railways on viaducts, very widespread particularly in Asia, are not included at all. Despite these limitations, it has been well produced and forms a record of the academic research outcomes of leading experts in the field that can surely be useful for the application of these techniques in practice and as a basis for further research.

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