



Editorial:

Noise and vibration from transportation

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Nowadays, railway ranks as an environmentally friendly and sustainable form of transport associated with a continuously expanding network. This success, often considered as the second “golden age” of rail, induces a vision of trains that should be quiet and vibrationless (Connolly et al., 2016; Vogiatzis and Kouroussis, 2017b). However, numerous environmental technical challenges are associated with railway infrastructure, including the assessment of urban railway vibrations and noise (Vogiatzis and Kouroussis, 2017a).

Prediction models are widely used at present to understand the nature of railway ground waves and their associated characteristics. Simulating excitation is of major concern and fixes the choice of a proper numerical model. Fig. 1 indicates the major sources of vibration originating from the passing of trains:

1. Moving load effect

This effect has been studied for several years, leading to many analytical and numerical prediction models. The associated problem is to determine the vibration level when a (constant) load is moving along a straight line on the surface of a half-space and generally at constant speed: the analogy with a moving railway vehicle is obvious. Specific situations can

be studied, such as the super-critical phenomenon appearing when a vehicle moves at a speed greater than that of the wave propagating into the soil (Krylov and Ferguson, 1994).

2. Distributed track unevenness

Rail and wheel surface geometries are not perfect. Unevenness makes contact between wheels and rails less than perfect and generates a dynamic excitation directly observable in the evaluation of railway-generated ground vibrations. Distributed rail unevenness data are often in the form of spectra (power spectral density) as a function of the spatial frequency (number of cycles per unit of length) with a specific shape, often defined in railway standards (Garg and Dukkipati, 1984).

3. Localized defects on the rail surface

Singular defects such as rail joints, switches, and crossings are a significant source of dynamic excitation on railway tracks. They appear mainly in urban environments, rather than in high-speed lines, and represent the main contributor of railway-induced ground vibrations, even at low vehicle speeds (Kouroussis et al., 2015). Noise generated by the passing of wheels over localized defects is also important.

4. Localized defects on the wheel surface

Typically, a flat spot or ‘wheel flat’ occurs when a wheelset is dragged along the rail due to emergency braking or during slip and slide conditions. In some cases, the dynamic effect of a wheel flat is of the same order of magnitude as a localized defect on a rail, with similar levels of ground vibration, in addition to the repetitiveness that occurs at one or more positions on the wheel circumference (Alexandrou et al., 2016).

Historically, the field of railway noise was studied before problems of railway vibration. Compared to aerodynamic noise, rolling noise and traction noise are dominant at low speed. The mechanisms of such noise are well understood by researchers in this field. In urban conditions, the dominant source of noise remains the rolling noise, generated by the

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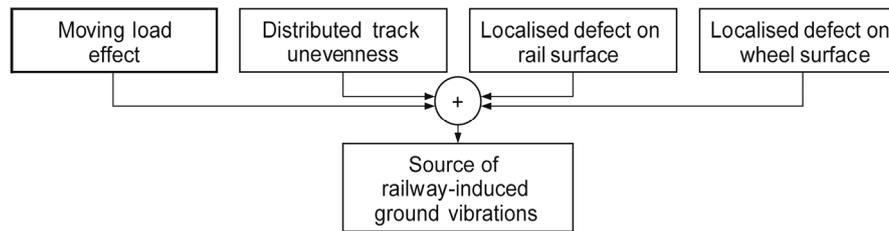


Fig. 1 Cumulative effect of different sources of railway-induced ground vibrations

interaction of rotating wheels and the rail. Vibroacoustic studies can be helpful to elucidate the generation mechanisms and reduce railway noise (Thompson, 2009).

Recently, much research has been devoted to the very complex theme of railway induced ground vibration and noise. The proposed topic of this special issue, covered by four papers, is the broad issue of the generation and propagation of sound and ground borne vibration from rail transport. Rail induced vibration has gained more attention in recent years. In this special issue, primary scientists on the leading edge in this field were invited to share their recent findings and expertise.

Auersch and Said (2021) present a comparison of the dynamic effects of ballasted and slab tracks through a mixed experimental/numerical study. This is an extended version of their conference paper (Auersch and Said, 2019), including additional results related to ballasted tracks. Artificial and real condition excitations were used to extract the track resonances and to analyze the stiffness of track elements, including all components of slab and ballast tracks. Track deflections and transfer functions were analyzed for various track and soil configurations. These observations were confirmed by numerical solutions, using the wavenumber domain method for the calculation of ballast and slab tracks. This hybrid analysis has some advantages, especially providing the possibility to corroborate the primary conclusions. In addition, the results presented provide a large database for transport sector specialists.

Lyratzakis et al. (2021) focus on high-speed trains and their effect on the neighborhood, with possible mitigation measures as a highlight. After a concise and efficient analysis of the possible solution (technically and economically speaking), they suggest the use of expanded polystyrene geofam blocks

as embankment material. It is well known that embankments play an important role in vibration propagation and attenuation. As waveguides trapping energy within them, their efficiency depends on the embankment material (Olivier et al., 2016). Hence, a numerical analysis was conducted using the finite element method for modelling the soil wave propagation, previously validated by Lyratzakis et al. (2020). The main geometrical parameters (height, slope) were analyzed to quantify the isolation properties of such blocks.

Zhang et al. (2021) studied the noise generated by trains running on an elevated railway. From a field test of an elevated metro line, the propagation and attenuation of emitted noise was analyzed in the time domain and the frequency domain (linear and one-third octave analysis, respectively). The noise beside a box girder bridge was deduced as a function of the energy and the spatial distribution. To evaluate the impact of bridge structure on noise, a structural model is proposed, based on a train/track/bridge model previously developed (Zhang et al., 2019). This approach offers a way to calculate the corresponding acoustic radiation, after having validated the proposed model. Using time and frequency domain analysis methods, the impact of the bridge structure on the bridge-side environmental noise was analyzed. Finally, the Doppler effect due to the moving source represented by a train was studied. It was proved that such an effect plays an essential role in the measurement analysis.

Zhao et al. (2021) devoted their research to floating slab tracks. Floating slab tracks represent a globally recognized mitigation solution for urban conditions (Vogiatzis and Kouroussis, 2015). However, an undesirable effect of this in terms of track design appears at low frequencies, at which vibration amplification can occur. To overcome this deficiency,

the authors suggest a novel mitigation measure based on the theory of quasi-zero-stiffness vibration isolators. After a detailed description of such systems, they establish a compound system involving railway vehicles, a floating slab track, and vibration isolators, based on the formalism proposed by Zhai and Sun (1994). In this way, they prove theoretically the improvement in low-frequency vibration reduction made possible by quasi-zero-stiffness vibration isolators. The next step should be the validation of this novel concept.

From these papers, there appears to be a need for harmonization of metrics used to assess structural vibration with respect to comfort and structural damage, similar to that proposed for airborne noise (Thompson et al., 2019). Indeed, recent research shows that national and international standards and recommendations provide different means of evaluating ground vibration based on specific motion metrics (Kouroussis et al., 2014). Numerical models offer a way to evaluate these structural vibrations and possible solutions to mitigate them, before testing physically (Kouroussis et al., 2019; Yang et al., 2019). At the same time, it is important to pay attention to the life-cycle performance of these new mitigation methods (Kaewunruen and Martin, 2018).

We hope that the most up-to-date views expressed in the four papers shared in this special issue demonstrate real potential for improving the urban environment. We also hope these research articles will promote discussion and provide benefits for journal readers.

Conflict of interest

Georges KOUROUSSIS, Sheng-yang ZHU, and Konstantinos VOGIATZIS declare that they have no conflict of interest.

References

- Alexandrou G, Kouroussis G, Verlinden O, 2016. A comprehensive prediction model for vehicle/track/soil dynamic response due to wheel flats. *Proceedings of the Institution of Mechanical Engineers, Part F: Journal of Rail and Rapid Transit*, 230(4):1088-1104.
<https://doi.org/10.1177/0954409715576015>
- Auersch L, Said S, 2019. Measurement of slab track behaviour at different sites. *Proceedings of the 26th International Congress on Sound and Vibration*.
- Auersch L, Said S, 2021. Dynamic track-soil interaction—calculations and measurements of slab and ballast tracks. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 22(1):21-36.
<https://doi.org/10.1631/jzus.A1900651>
- Connolly DP, Marecki G, Kouroussis G, et al., 2016. The growth of railway ground vibration problems—a review. *Science of the Total Environment*, 568:1276-1282.
<https://doi.org/10.1016/j.scitotenv.2015.09.101>
- Garg VK, Dukkipati RV, 1984. *Dynamics of Railway Vehicle Systems*. Academic Press, Toronto, Canada.
<https://doi.org/10.1016/B978-0-12-275950-5.X5001-9>
- Kaewunruen S, Martin V, 2018. Life cycle assessment of railway ground-borne noise and vibration mitigation methods using geosynthetics, metamaterials and ground improvement. *Sustainability*, 10(10):3753.
<https://doi.org/10.3390/su10103753>
- Kouroussis G, Conti C, Verlinden O, 2014. Building vibrations induced by human activities: a benchmark of existing standards. *Mechanics & Industry*, 15(5):345-353.
<https://doi.org/10.1051/meca/2014041>
- Kouroussis G, Connolly DP, Alexandrou G, et al., 2015. The effect of railway local irregularities on ground vibration. *Transportation Research Part D: Transport and Environment*, 39:17-30.
<https://doi.org/10.1016/j.trd.2015.06.001>
- Kouroussis G, Zhu SY, Olivier B, et al., 2019. Urban railway ground vibrations induced by localized defects: using dynamic vibration absorbers as a mitigation solution. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 20(2):83-97.
<https://doi.org/10.1631/jzus.A1800651>
- Krylov V, Ferguson C, 1994. Calculation of low-frequency ground vibrations from railway trains. *Applied Acoustics*, 42(3):199-213.
[https://doi.org/10.1016/0003-682X\(94\)90109-0](https://doi.org/10.1016/0003-682X(94)90109-0)
- Lyratzakis A, Tsompanakis Y, Psarropoulos PN, 2020. Efficient mitigation of high-speed trains induced vibrations of railway embankments using expanded polystyrene blocks. *Transportation Geotechnics*, 22:100312.
<https://doi.org/10.1016/j.trgeo.2019.100312>
- Lyratzakis A, Tsompanakis Y, Psarropoulos PN, 2021. Mitigation of high-speed trains vibrations by expanded polystyrene blocks in railway embankments. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 22(1):6-20.
<https://doi.org/10.1631/jzus.A1900680>
- Olivier B, Connolly DP, Costa PA, et al., 2016. The effect of embankment on high speed rail ground vibrations. *International Journal of Rail Transportation*, 4(4):229-246.
<https://doi.org/10.1080/23248378.2016.1220844>
- Thompson D, 2009. *Railway Noise and Vibration: Mechanisms, Modelling and Means of Control*. Elsevier, Oxford, UK.
- Thompson DJ, Kouroussis G, Ntotsios E, 2019. Modelling, simulation and evaluation of ground vibration caused by rail vehicles. *Vehicle System Dynamics*, 57(7):936-983.
<https://doi.org/10.1080/00423114.2019.1602274>
- Vogiatzis K, Kouroussis G, 2015. Prediction and efficient

- control of vibration mitigation using floating slabs: practical application at Athens metro lines 2 and 3. *International Journal of Rail Transportation*, 3(4):215-232. <https://doi.org/10.1080/23248378.2015.1076622>
- Vogiatzis K, Kouroussis G, 2017a. Airborne and ground borne noise and vibration from urban rail transit systems. In: Yaghoubi H (Ed.), *Urban Transport Systems*. InTechOpen, p.61-87.
- Vogiatzis K, Kouroussis G, 2017b. Environmental ground-borne noise and vibration from urban light rail transportation during construction and operation. *Current Pollution Reports*, 3(2):162-173. <https://doi.org/10.1007/s40726-017-0059-3>
- Yang JJ, Zhu SY, Zhai WM, et al., 2019. Prediction and mitigation of train-induced vibrations of large-scale building constructed on subway tunnel. *Science of the Total Environment*, 668:485-499. <https://doi.org/10.1016/j.scitotenv.2019.02.397>
- Zhai WM, Sun X, 1994. A detailed model for investigating vertical interaction between railway vehicle and track. *Vehicle System Dynamics*, 23(S1):603-615. <https://doi.org/10.1080/00423119308969544>
- Zhang YF, Li J, Chen ZW, et al., 2019. Dynamic analysis of metro vehicle traveling on a high-pier viaduct under crosswind in Chongqing. *Wind and Structures*, 29(5): 299-312. <https://doi.org/10.12989/was.2019.29.5.299>
- Zhang YF, Li L, Lei ZY, et al., 2021. Environmental noise beside an elevated box girder bridge for urban rail transit. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 22(1):53-69. <https://doi.org/10.1631/jzus.A1900678>
- Zhao ZM, Wei K, Ren JJ, et al., 2021. Vibration response analysis of floating slab track supported by nonlinear quasi-zero-stiffness vibration isolators. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 22(1):37-52. <https://doi.org/10.1631/jzus.A2000040>

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Guest Editor-in-Chief

Prof. Georges KOUROUSSIS is an editorial board member of *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)* since 2018. He is an Associate Professor in the Department of Mechanical Engineering at the University of Mons, Belgium. He graduated from the Faculty of Engineering of Mons with a magna cum laude honours degree in mechanical engineering in 2002, and started to work as a research and teaching assistant at the University of Mons. He obtained his PhD from the University of Mons in 2009. He was an invited researcher in the National Technical University of Athens (Greece) before being appointed to the academic staff in the University of Mons. Since 2010 he has been Senior Research Assistant, Senior Lecturer, and Associate Professor. His research interests are in the environmental impact of vibrations induced by the railway traffic, the simulation of multibody models, signal processing for effective vibration analysis, the soil-structure interaction, and the modal analysis.

Prof. KOUROUSSIS is an Associate Editor of several international journals (*Shock and Vibration*, *Transport*, and *Railway Engineering Science*). He also serves in the editorial board of *International Journal of Rail Transportation*, *Urban Rail Transit*, and *MDPI/Sustainability*. He was also Director of the International Institute of Acoustics and Vibration (IIAV) for the period 2016–2020. He has published 70+ SCI journal articles and 100+ conference papers.

Guest Editors



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