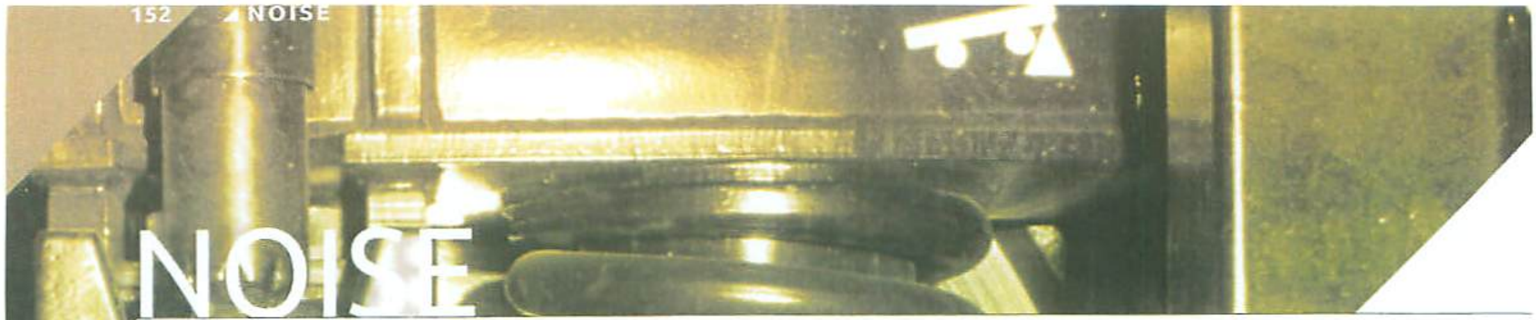


# THE RIVAS TOOLBOX FOR VIBRATION MITIGATION

WHILE PLENTY OF RESEARCH[1] HAS BEEN CARRIED OUT ON RAIL-GENERATED NOISE, SINCE VIBRATION IS LESS PERCEPTIBLE IT TENDS TO RECEIVE LESS ATTENTION. TO FILL THIS GAP, EUROPEAN PROJECT RIVAS[2] – RAILWAY INDUCED VIBRATION ABATEMENT SOLUTIONS – IS EXPLORING LOW-FREQUENCY GROUND-BORNE VIBRATION WITH A VIEW TO REDUCING ITS ENVIRONMENTAL IMPACT, WHILE SAFEGUARDING THE COMMERCIAL COMPETITIVENESS OF THE RAILWAY SECTOR.

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The causes of ground-borne vibration are track and wheel irregularities, and/or static (loads moving along the track) and dynamic (discreet sleeper spacing) excitation. Very low frequencies below 30Hz can cause vibration problems, while above this level, 'vibration-induced noise' is the main consequence.

While vibration causes buildings to shake (ask anyone living in a flat built over or next to certain line, see photo right), ground-borne vibration transmitted to buildings through the floors and walls transforms into 'ground-borne noise'. "People in general are becoming more and more sensitive to the impact of both noise and vibration," explains Bernd Asmussen, RIVAS coordinator, "plus the volumes of traffic are increasing," The European Union, for one, is strongly backing freight transport by rail as an environmentally friendly alternative to other modes of transport. It has provided €450 million of support for the 2nd Marco Polo programme (2007-2013)[3] for projects to shift freight transport from the road to sea, rail, and inland waterways.

But for people living along vibration hot spots, i.e. major traffic lines, and freight corridors in particular, more traffic is bad news. By way of example, creating the freight corridor between the seaports of Antwerp and Rotterdam down to Milan/Genoa has meant expanding some stretches of rail track in Germany from two to four paths. Yet unless the industry takes action now, ground-borne vibration is not going to go away. "Shifting more traffic from the roads to rail means building or upgrading tracks," says Mr Asmussen, "and we are seeing increasing opposition to such projects because of the noise and vibration problems. Furthermore, the costs of mitigation measures are often enormous, which then makes it questionable whether the lines get built at all."

Surprising though it may seem, noise barriers are also partly to blame for people's growing intolerance of vibration. Rail noise tends to 'mask' the impact of vibration, but if noise barriers are erected, the vibration remains and becomes more exposed – and so a greater cause for complaint.

## FIRST AID TOOLKIT

RIVAS has three years to explore ways and means of reducing vibration in residential areas near railway lines to values near or even below the threshold of perception. In practical terms this means developing a toolbox of products such as rail-fastening systems, sleepers, resilient elements for track and sub-grade, as well as for rolling stock, together with technologies to reduce vibration on the propagation path, to meet the specific needs of end users, i.e. surface line railway operators and infrastructure managers. And although the team is focusing on low-frequency vibration from open lines (a concern mainly for freight traffic), its results are likely to apply to suburban, regional, and high-speed operations. "The problem concerns mainly surface lines used for freight and regional trains, since high-speed lines tend to be built away from residential areas," Mr Asmussen reminded EURAILmag.

The consortium of 26 partners is made up of train operating companies, infrastructure managers, manufacturers, suppliers, consultancies, universities, and associations (see box, p.155). Its integrated approach – comprising the whole system, modelling, prototype construction, lab testing, and field tests – has been divided into eight[4] work packages (WP).


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Surface lines may case vibration or vibration-induced noise

**WP 1: Assessment and monitoring procedures**

The main objective of WP1 is to establish test procedures to efficiently monitor and control the performance of vibration mitigation measures under realistic conditions, together with their effect on residents.

More specifically, this implies defining various procedures. One will serve to evaluate the reduced vibration level in terms of human exposure, considering vibration and vibration-induced noise, and taking into account legislation

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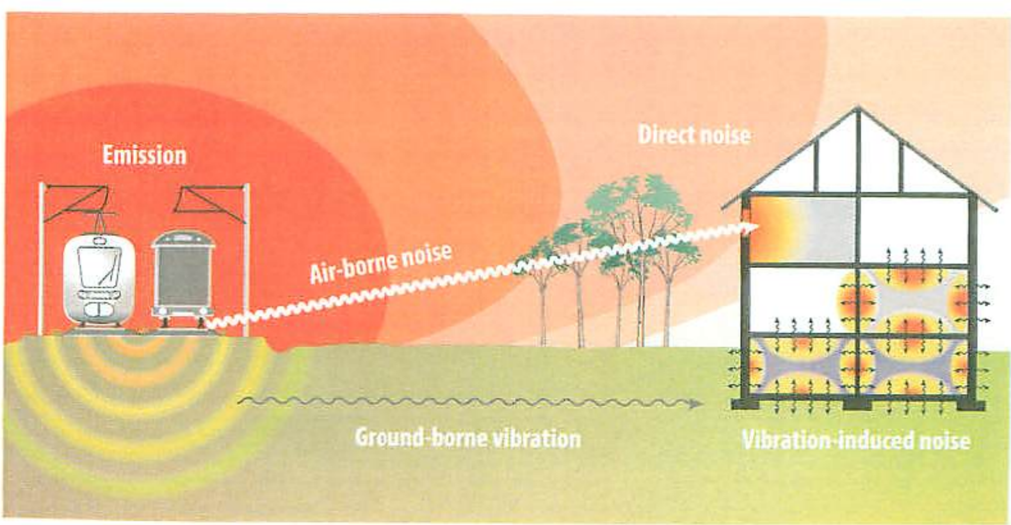

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and evaluation procedures in European countries.

Another 'test' procedure will serve as a protocol for calculating the performance of mitigation measures studied in WP2, WP3, WP4, and WP5. And thirdly, in order to transfer the performance obtained for a particular set of rolling stock, track, and soil characteristics to a reference situation and vice versa, a procedure will be elaborated. This will enable the performance of various mitigation measures at different sites to be compared and their results extrapolated to other sites.

Particular emphasis is being put on the test procedures required to assess the dynamic soil characteristics, since they influence the performance of mitigation measures. Activities here include methods based on 'in situ' geophysical and laboratory tests, plus classical soil mechanics tests, and their validation, the collection of data from soil testing into a database and recommendations for standards (soil properties).

### WP 2: Mitigation measures at source

The team responsible for this package is drawing up, optimising, and demonstrating selected measures related to track and rolling stock maintenance. The goal is to reduce the excitation of ground vibration at source. More specifically, this work implies:

- identifying the different types of track and wheel irregularities and their influence on vibration generation
- working out the most efficient maintenance measures for the track, e.g. hanging sleeper, track geometry, switch, and wheels, e.g. out-of-roundness and wheel flats, to minimise the emission of vibrations
- performing full-scale demonstrations of certain key maintenance measures for both the track, such as ballast tamping and grinding, and wheels, e.g. turning.

### WP 3: Mitigation measures on track

This WP is tackling ground vibrations at source by developing and optimising mitigation measures on the track itself. Since the track characteristics (pad stiffness, fastening system, sleepers…) play a key role in generating ground vibrations, efficient mitigation measures can be designed to modify the track response, and hence resulting in low vibration emission in the ground. Activities cover ballasted in-line track, curves, switches, and slab track. Ballasted track has been given priority over slab since the former is more commonly used for freight and conventional speed traffic – the focus of RIVAS. Furthermore vibration is less of a problem with slab track since it distributes the loads of travelling trains over longer distances. "But we do have an activity within the scope of the project [see list below] for improving the performance of slab track," adds Mr Asmussen, "since it isn't perfect either."

The following tasks are scheduled:

- assessment of the state-of-the art technology used for existing vibration mitigation measures, and the definition of priorities for future work
- development of vibration mitigation measures based on improved rail fastening systems and sleeper/ballast interaction
- assessment of the potential of under-sleeper pads as a vibration mitigation measure for curves. Mr Asmussen: "One of the solutions for mitigating vibration is to put a


Excitation mechanisms

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**26 partners:**
**Suppliers:** Alstom, Bombardier, Eiffage, Keller Holding, Lucchini, Pandrol, RailOne, Sateba, and UNIFE
**Research institutes:** BAM, CEDEX, Chalmers University, CSTB, ISVR, KU Leuven
**Consultants:** D2S, Satis, TÜV Rheinland, and Vibratec
**End users:** ADIF, Deutsche Bahn, RATP, SBB, SNCF, and Trafikverket

soft elastic material somewhere on the track. And while under-sleeper pads do work, there is a danger of them having a negative impact on the stability of the track itself."

- better understanding of the phenomena causing ground vibrations via switches and the subsequent design of efficient mitigation measures
- classification of existing slab track systems with respect to emission of ground vibrations and the development of mitigation measures with focus on the sleeper/slab interface

**WP 4: Mitigation measures on transmission/propagation**
The team is working to develop and optimise railway infrastructure-based vibration reduction technologies in the transmission path, either under or next to the track. In the frequency range of railway vibration, the top layer of soil plays an important role, but one that is often neglected. It leads to a 'cut-on frequency' above which a steep rise in the vibration transmission spectrum occurs. In these studies, the approach involves taking the layered ground structure into account or altering its effect to form barriers to propagation. "Soil determines how fast vibration travels, with very soft soil, particularly in Sweden and in parts of Germany and the Netherlands, being the worst case, because vibration travels through it at a relatively low speed," adds Mr Asmussen. "When the train is travelling faster than the transmission speed of the vibration this creates a kind of 'supersonic boom' that sends shockwaves through the ground. And these can be powerful enough to threaten superstructures and/or trains."

Mitigation technologies for use in the vibration transmission path will be developed and tested, placed close to the track so that they are still regarded as part of the railway infrastructure. Options under study include trenches, structural barriers (buried walls), subgrade stiffening, horizontally layered wave-impeding blocks, and resonant reflectors (heavy masses on soil next to the track). The reference sites being used are Horstwalde (Germany), Groene

Hart (the Netherlands), Lincent (Belgium), Steventon (U.K.), Ledsgaard (Sweden), together with two test sites on the Adif (Spain) and Trafikverket (Sweden) networks. They include a wide range of soil conditions, representative of different regions in Europe, but with geophysical features – homogeneous soil, soft top layer and inverse layering – shared by many other sites where problems with railway-induced vibrations may occur.

At least two vibration mitigation technologies on or close to existing railway lines will be tested during the project, and their effective reduction measured in the field tests. The costs of each successful option will be calculated, and their design guidelines and engineering constraints compiled, to form a 'technology assessment' of the technique. To date, preliminary numerical results obtained from the specific sites under concern suggest that:

- soft and stiff wave barriers reduce vibration levels in the upper frequency range
- subgrade stiffening significantly reduces vibration levels in the lower frequency range
- introducing 'wave-impeding blocks' (WIB) under the track results in limited reduction below the cut-off frequency, but a considerable increase in reduction above it
- although resonant reflectors (multiple component assemblies of several plane-parallel plate substrates separated by a precisely chosen air gap) can have a positive effect in the near field, this is rather negative in the far field.

**WP 5: Mitigation measures on vehicles**

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**"While others have tended to focus on just one sub-system, our team of researchers, universities, manufacturers, and end-users are dealing with the whole system"**

The core tasks in this package involve firstly identifying and quantifying the major vehicle-related parameters influencing vibration, followed by the creation of a database with these parameters. Furthermore work is being performed to optimise measures to reduce vehicle-induced vibration, taking into account functional constraints and cost efficiency aspects. The most promising mitigation measures will be implemented and validated in a full-scale field test at selected sites.

"With its 26 partners, RIVAS is the biggest European project of its kind," points out Mr Asmussen. "Furthermore, while others have tended to focus on just one sub-system, our team of researchers, universities, manufacturers, and end-users are dealing with the whole system."

## IMPLEMENTATION & ANTICIPATION

With the needs of end-users foremost in mind, come 2013 RIVAS will be keen to put its results into practice, and to see an extensive and fast implementation of the technical developments achieved. "In the past, people tended to ignore rail noise problems – hence we are very behind with mitigation measures," says Mr Asmussen. "We want to avoid the same situation for vibration." Yet at the same time, to avoid endangering the competitiveness of rail traffic, all the solutions proposed will be subject to life cycle costing to avoid them being cost-prohibitive. For example, typical noise barriers, depending on their height, add between €2 to 4 million per 1km of track.

As well as contributing to controlling people's exposure to vibration and vibration-induced noise caused by rail traffic, the RIVAS results should also contribute towards establishing European standards, in particular the harmonisation of metrics. "Right now there is legislation at both national and European level for rail-generated noise, but not for vibration. We expect the situation to change over the next 10 to 15 years," predicts Mr Asmussen ■

**Lesley Brown**

*References*
*[1]for example, INNOTRACK, STAIRRS, SILENCE, Eurosabot, amongst others*
*[2]www.rivas-project.eu*
*[3]http://ec.europa.eu/transport/marcopolo*
*[4]WP 6: Dissemination, exploitation, and training; WP 7: Financial and contract management; WP 8: Technical coordination*