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**RAILWAY NOISE AND VIBRATION –
CURRENT EUROPEAN LEGISLATION AND RESEARCH AND
MEASUREMENTS ON SERBIAN RAILWAY**

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Abstract: In this paper certain current European noise legislation, standards and research including the Physical Agents Directive, the Environmental Noise Directive 2002/49/EC and the Technical Specifications for Interoperability are summarised and their implications in terms of maintaining the track are discussed. In the Environmental Noise Directive a number of research projects investigated noise mapping. From this Directive the action plans for control of noise on the environment follow. Measurements of noise and vibrations on Serbian Railway, before and after track reconstruction, are presented at the end.

Key words: railway, track, noise, vibration, measuring

1. INTRODUCTION

Railway operating noise originates from several sources, such as: rolling (wheel-rail interaction), traction (locomotive engine, fans and gears), aerodynamic effects (pantograph, body turbulence) and so on. The vibrating track and vehicle components radiate airborne sound into the environment. Also, structure-born vibrations are transmitted into the soil, from where propagate in neighboring buildings. The noise and vibration levels depend not only of the vehicle properties, but also of the design and state of the track.

The dominant contributor, over the widest speed range (from around 50km/h to around 270km/h) is wheel-rail rolling noise. It is a function of the vibratory excitation of the vehicle and track system, from the wheel and rail roughness during wheel rolling. Rail roughness is the result of the vertical dynamic rail displacement, rail burns, dished joints and so on. Rolling noise depends also of vehicle hanging parameters, track parameters and support structure parameters such as sleepers, ballast or slab, bridge girders. Corroded wear of running rail surface can cause the rolling noise 20dB(A) greater than the smooth rail.

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2. EUROPEAN LEGISLATION AND STANDARDS

Currently there are two main areas of legislation on environmental noise originating from the European Commission, which have an impact on the railway industry:

- Environmental Noise Directive and
- Interoperability Directives

The regulations by the European Union - Physical Directive 2003/10 (Block, 2005) were adopted and the main implication of these regulations is to reduce the noise level in the cabin of the train by 5 dB. The control of noise in conjunction with the wheel-rail track maintenance is essential to meet these regulations.

Environmental Noise Directive (END) of the European Parliament and Council of 2002, which refers to the assessment and management of noise, is directed towards defining the common approach in order to avoid, prevent or reduce the harmful effects, including disturbance, considering the exposure to noise in the railway vicinity.

Key activities are:

- determination of exposure to environmental noise by noise mapping,
- provision of information on environmental noise and its effects on the public,
- adoption of action plans, and
- preservation of the state of environmental noise quality where it is good.

Noise maps provide an overview of the ambient noise climate in cities and major transportation sources such as road, rail and air traffic, and from industrial activity. The maps account for the number of people affected by different levels of ambient noise and the source of that noise. The exposure of the population is based on the anticipated average dose of noise over one year (www.defra.gov.uk/noisemapping).

Used noise indicators are:

- L_{den} as the A-weighted equivalent noise level for day, evening and night periods,
- L_{night} as the A-weighted equivalent noise level for night.

These noise maps have been produced to meet the requirements of the Environmental Noise Regulations 2006 (UK) and END. The action plans will seek to manage noise issues and effects, including noise reduction if necessary, based on the results obtained through the mapping process. In order to prepare itself for the requirements of the END, the UK government carried out the pilot project of mapping by 2007 and with more details by 2012.

An example map of a graphical representation of noise level is presented in Fig. 1 [1].

The roughness of the rail head is one of the important problems in the prediction of noise. Government in the UK carried out an analysis to find the impact of the actual roughness of rails and wheels, because the dominant rolling noise is caused by a combination of wheel and rail roughness on their contact. The research study was developed in 2004, which takes into account the roughness and provides action plans that lead to smoother rails.

The conclusions of this study were:

- Noise for the average train speed of 160 km/h predicted by calculation would be about 4 dB lower;
- Depending on the mixture of speeds and trains, in some places actual L_{den} can be 20 dB higher than the predictions using the calculation in project.

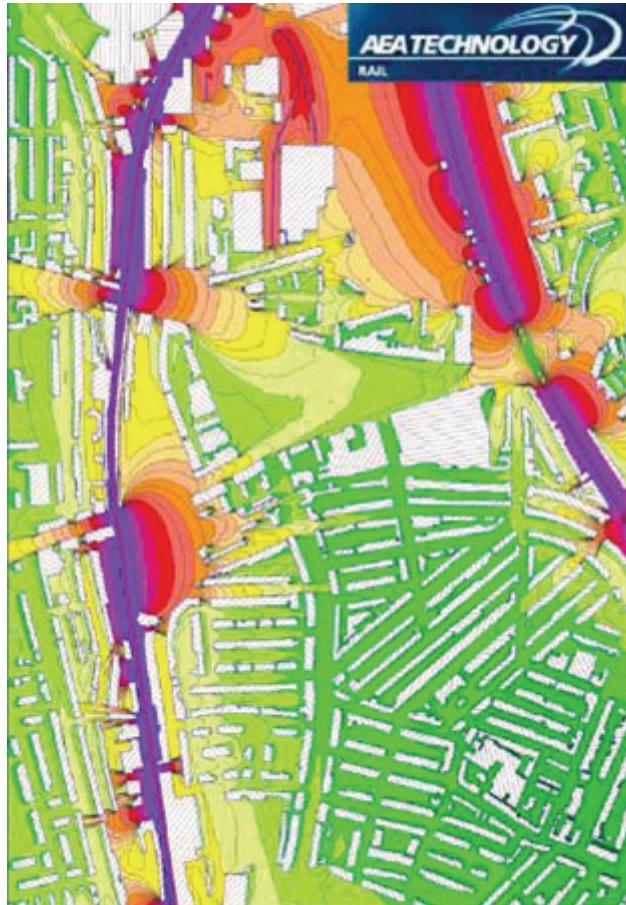


Fig. 1 Example of a noise map

The Technical Specifications for Interoperability relating to the rolling stock of the European high-speed rail system referred to the High Speed Interoperability Directive came into force in 2002. It contains the noise emission levels for new high speed stock. The Technical Specifications for Interoperability for the new conventional stock encompasses freight wagons, non high speed coaches, diesel and electric locomotives and multiple units. After the discussion, the noise levels were specified for passing, stationary and accelerating vehicles [1].

3. EUROPEAN RESEARCH PROJECTS

In order to meet the requirements of the Directive, the European Commission began funding two research projects. First, within the 5th Framework research, the technological development program HARMONOISE was completed in late 2004. It is focused on the characteristics of noise sources from road and rail separately. The meteorological condi-

tions are taken into consideration and the propagation models can be applied for various sources. Another project under the 6th Framework research team is IMAGINE. This project extends the consideration of HARMONOISE project on industry and aviation and is designed to provide guidelines, examples and a database for quick and easy implementation and harmonization of methods arising from these two projects [1].

A number of studies on the vibrations transmission were made by ORE D151 [2]. Fig. 2 shows the range of acceleration on the building first floor during the passing train at a speed of 60km/h. The experiment examined three wheel states: newly re-profiled wheels, wheels worn after the passed 150000km and the wheels in service after 150000km with the flats from sliding occurring during breaking.

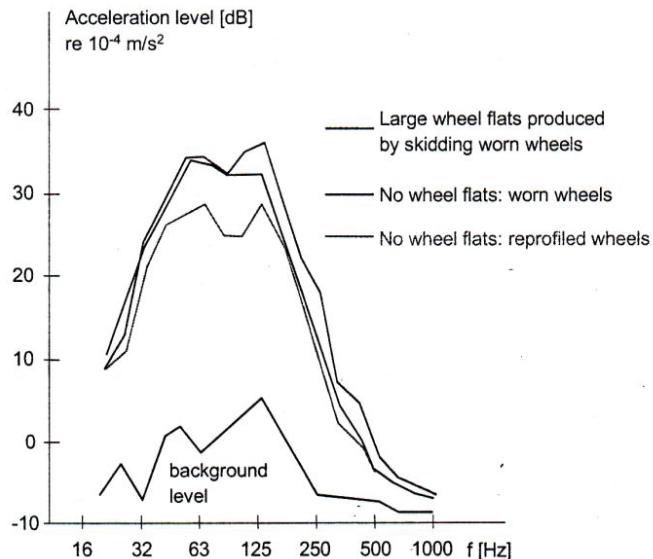


Fig. 2 Measured vibration on the building near the subway

As it can be seen from the Fig. 2, measured accelerations are in the frequency range of 30-250Hz. Wheel worn during the operation, compared with newly re-profiled wheel, shows a significant increase in vibration from 5 to 10dB. Flats of the wheel produced a further increase of vibration, of 5dB at frequencies above 60Hz. The energy from wheels is furder transferred to the building at higher frequencies and produces acoustic effect that increases noise by 5dB(A).

The vibrations increment in the ground may also be expected from irregularities in the rails, in particular defects of joints and rolling surface defects. Because of its short wavelength, the rail corrugation will not significantly contribute to the ground vibration with low frequency. The difference between the rails with joints and the continuously welded rails is not greater than 5dB.

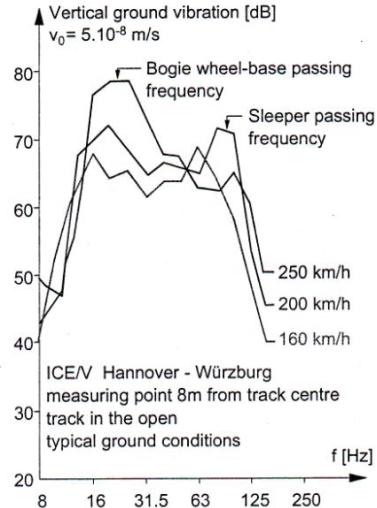


Fig. 3 The effect of high speeds on ground vibrations

Measurements at the German railway (DB) high-speed line Hannover-Würzberg (Fig. 3), show that serious vibrations may appear at frequencies that correspond to the axle spacing of the bogies. At speeds of 250 km/h measured values are middle of the square root of 78 dB with $V_0 = 10^{-8} \text{ m/s}$ for 1/3 octave width.

Another example of vibrations caused by the railway is the use of Dynamic Track Stabiliser (DTS). High energy, which is transmitted to the local track results in strong ground vibrations, mainly spread as Rayleigh waves in the surrounding area. Holland railway (NS) performed the measurements of acceleration at different distances from the track. From the measured results, presented in Fig. 4, it becomes clear that, according to DIN 4150, DTS machine should not pass the buildings closer than 15m. At a distance of 20m from the track, DTS causes the same level of vibration as train that transporting minerals.

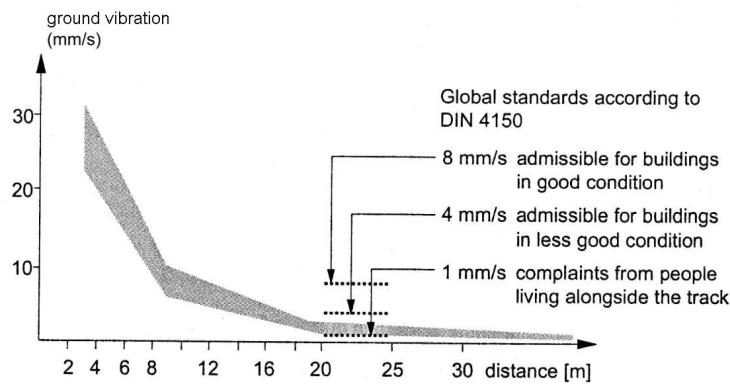


Fig. 4 Measured ground vibrations caused by DTS

4. MEASURINGS ON SERBIAN RAIL WAY

At Serbian Railway the noise and vibration measuring at the railway line Nis-Dimitrovgrad-Bulgarian border was conducted in October 2007, by the research institute "Kirilo Savic" from Belgrade [4]. The two different states of the track (before and after the reconstruction) are investigated.

Equipment for measuring the vibrations are acceleration sensor and acquisition system Spider (Fig. 5).

The vibration actions are exposed by the acceleration or the amplitude of vibration, frequency, acting time and the direction of vibration (z is vertical direction, y is horizontal direction normal to the track axis and x is horizontal direction parallel to the track axis).



Fig. 5 Measuring devices for vibrations

By analyzing the recording diagrams, the maximal amplitude and frequency of induced vibrations during train passing are determined. They are of a random character, depending of a wheel state, a train velocity, a vehicle mass, a track state and even the sort of a ground.

Especially, objects near the turnouts and the level crossings are of interest for this kind of measuring, because the track is usually in the bad condition there, the sleepers have the significant vertical displacements and the expected vibration level unpleasant for the people is between 0,5 and 2Hz.

The vibration duration is not exceeding 30s for the long freight trains with the low speed.

The maximal amplitudes appeared for the vertical vibrations. The amplitudes of vibrations in horizontal plane, normal to the track are greater than parallel to it.

The vibration measurements on unreconstructed track are carried out near the level crossing, at 8m from the track, and at the source (Fig. 6). On the reconstructed part of the track the test points are also near the level crossing, at 9m from the track, and at the source (Fig. 7).

The received measuring results show the vibration dependence on the track maintenance state. Also, the great dependence on the train velocity is noticed. The distinct vibration amplitudes are in vertical direction, at the source, in amount of $0\text{-}45\text{m/s}^2$. The frequencies are in expected limits, between 18 and 40Hz.

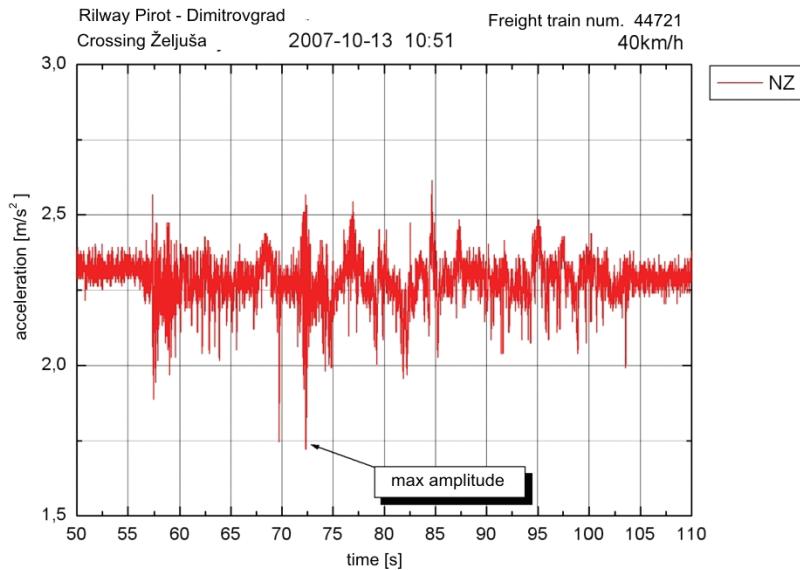


Fig. 6 Diagram of acceleration on the sleeper, unreconstructed track

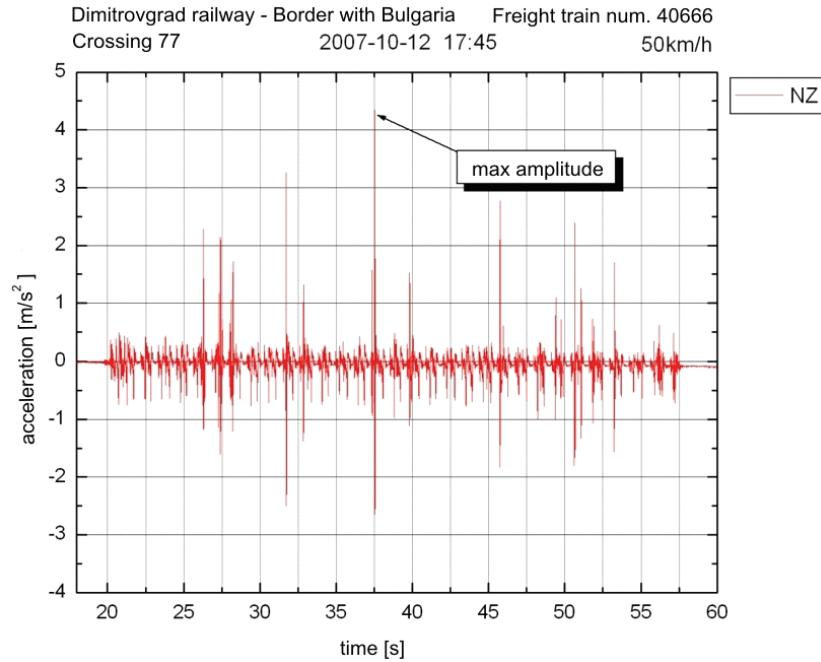


Fig. 7 Diagram of acceleration on the sleeper, reconstructed track

The equipment for measuring noise was a precision digital fonometar. The measuring was conducted on the building wall at 10-25m from the track, at the elevation of 3,5m above the rail rolling surface. The recording interval is 5s. The noise diagrams for day and night regime are given in the Figs 8 and 9.

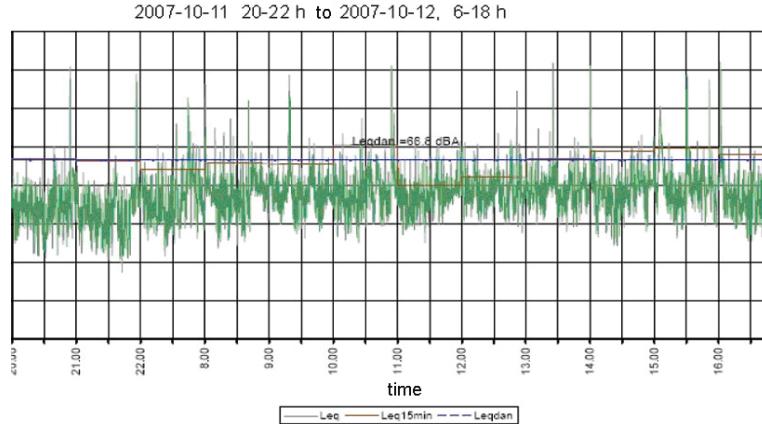


Fig. 8 Diagram of noise for day regime

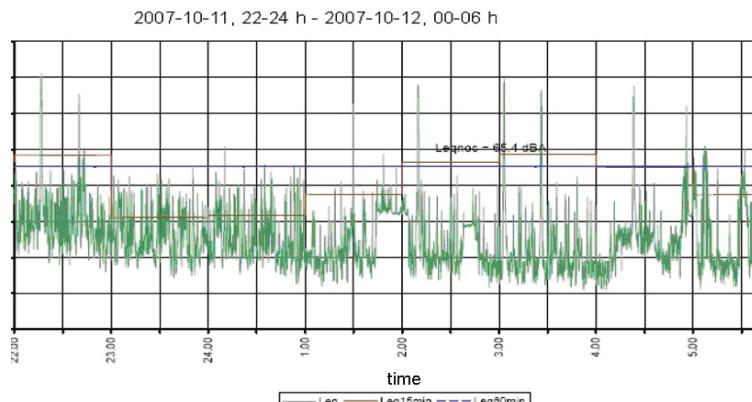


Fig. 9 Diagram of noise for night regime

By analyzing the recording diagrams, it can be conducted that the rolling of the trains through the urban surrounding leads to the great increase of noise level. At the measuring example, the noise was from 55 to 80dB(A) for day regime and from 51 to 80dB(A) for night regime, that exceeds the permitted level. The increase of noise level is directly influenced by the velocity and the length of the train, the traffic density, and especially the state of the rolling stock.

5. CONCLUSION

European railway noise and vibration legislation is in force or in final development. The research projects examine the achieved compliance with this legislation. One of the key activities is the noise mapping and the action plans in order to reduce the noise and vibration levels where necessary.

The measuring on Serbian Railway shows the great importance of track maintenance state on the noise and vibration levels in the track vicinity. Partial or total track renewal lowers the noise and vibration level, what is especially important by urban environment.

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BUKA I VIBRACIJE NA ŽELEZNICI – SAVREMENO ZAKONODAVSTVO I ISTRAŽIVANJE I MERENJA NA ŽELEZNICAMA SRBIJE

Mirjana Tomićić-Torlaković, Svetislav Stefanović

U radu se diskutuju izvesno savremeno evropsko zakonodavstvo i istraživanja, uključujući Direktivu za zastupnike fizike, Direktivu za buku u okolini 2002/49/EC i Tehničke specifikacije za interoperabilnost. U Direktivi za buku u okolini neki istraživački projekti istražuju mapiranje buke. Iz te Direktive proističu akcioni planovi za kontrolu buke u okolini.

Na kraju rada su prikazana merenja buke i vibracija na Železnicama Srbije, sprovedena pre i posle rekonstrukcije koloseka.

Ključne reči: železnica, kolosek, buka, vibracije, merenje