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NOISE CONTROL FOR A BETTER ENVIRONMENT

NOISE FROM URBAN TRANSPORT, NOISE EMISSION OF TRAMS

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ABSTRACT

Rail-bound traffic is the most sustainable means of transportation, as it consumes less energy, needs less space and produces less CO_2 than other means of transportation. However, noise produced by rail-bound traffic is still a major challenge. Occupants of buildings close to tram track are seriously disturbed by tram noise. In some instances, people outside the buildings are also affected. The problem is aggravated when maintenance of the track is not satisfactory. This research intends to describe main dynamic characteristics of the track and how rail noise is produced and propagated. Several measurements have been made. This paper presents the effect of track on the noise spectrum from the track.

Keywords: Tram, noise, vibration
I-INCE Classification of Subject Number: 43

1. INTRODUCTION

Increasing urbanisation and denser cities give rise to a need for transportation that produce little pollution and take up little space as possible. Rail-bound public transport running on electric power fills this bill nicely. However, noise impact from urban transport is still a key issue.

Many studies have been published about particularities of urban rail-bound transport as a noise source [1]. A compendium of studies for metro trains and trams in Norway, show that noise emission from metro trains and trams come mainly from rolling noise and traction noise [2, 3].

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The rolling noise is originated from the contact point between the rail and wheel of the train and depends on the roughness of them both. The traction noise is mainly dependent on the type of train. In general, noise sources are somewhat influenced by the train speed. The transition from traction noise to rolling noise and from rolling noise to aerodynamic noise as a function of train speed is shown in Figure 1. The absolute and relative noise levels shown in Figure 1 are only indicative and will vary with the type of train.

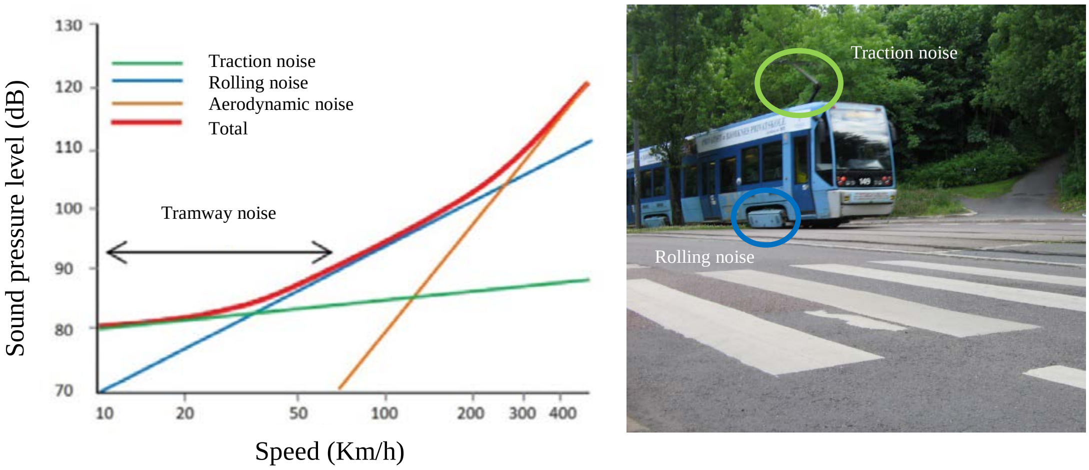

Figure 1 Sound pressure level for typical noise sources at different speed range [1]

In Norway, tramways operate in Oslo, Trondheim and Bergen. This article builds on measurements of noise and vibrations from trams and metros of Oslo. The two models of trams that operate in Oslo are: SL-95 and SL-79, see Figure 2.

Figure 2 Trams and metro in Oslo. Tram type SL-79 (left), tram type SL-95 (right)

The aim of this study is to describe the structurally transmitted noise along the rail, registered in some points along the tram network in Oslo. The structural noise can be heard several seconds before the tram passes by the measurement point. Noise complaints are often registered in residential areas. This paper intends to describe dynamics characteristics of the track and how the noise is developed/produced.

2. FASTENING SYSTEMS OF TRAMWAY IN OSLO

Tramway track used in Oslo is profile 49E1, type 900A which has a tensile strenght of 900 MPa. This profile is the same for tram and metro. In the city’s streets where the tram shares the way with other transport means is used the profile 60R2, type 700. The profile 49E1 is mounted on metal levels plate and is attached to concrete sleepers with bolted rail clips. Sleepers are located 600 cm apart in a ballast with small rocks. Figure 3 shows one overview of the profile 49E1.

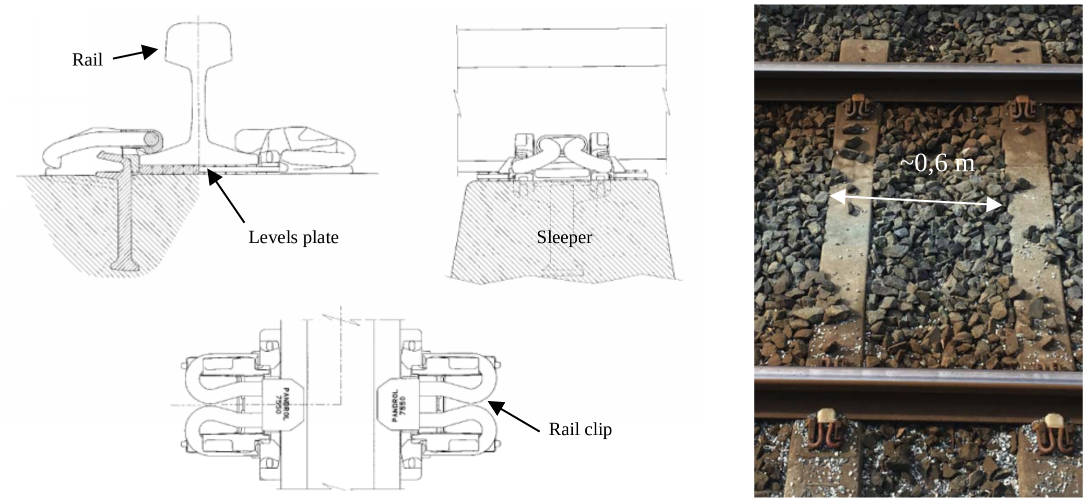

Figure 3 Fastening system of tramway and metro in Oslo, profile 49E1

3. DESCRIPTION OF THE MEASUREMENTS ON THE FIELD

3.1 Sound and vibration’s measurements

A vast number of measurements have been conducted in different locations along the tram line and metro systems in Oslo. Since 2011 noise from trams have been registered in 10 fixed locations. Olafsen and Stensland [4] shows an overview of noise levels from trams in Oslo. An overall effect of different variables, such as distance, speed, rail corrugation, is also discussed in their research. Their research is based on all the measurements registered in the last years (1780 tram passages). Vibrations from trams in Oslo were included in monitoring program in 2016. Results of comprehensive analysis for noise and vibration with 11 fixed measurements points is found in [5]. The roots of the research on vibration transmission into the surroundings can be traced back to 2013 [6].

Previous studies show a global analysis of noise and vibration. This research intends a detailed analysis for one of the eleven measure points. In this measurement point is possible to hear a train noise / structural noise before the tram passing.

Measurements from the environmental noise monitoring program consist in two microphones and two geophones located at approximately 5 meters and 10 meters from the closer track line, see Figure 4. Data is registered by train direction (inbound and outbound).


Figure 4 Position of microphone and geophones during measurements

Measurements were carried out with the following measuring equipment:

Containing:	Instrument:	Serial number:
Mic Preamp	NOR1201	19933
Mic	NOR1225	106901
Calibrator	BK4231	2123006
Mic Preamp	NOR1201	17594
Mic	NOR1225	08538
Calibrator	BK4231	1790978
Geophone	NOR1292	1292614
Geophone	NOR1292	1292626

3.2 Track decay measurements

In order to obtain a complete image of how the noise travel on the track, it was measured the vibration wave that is propagated along the track following guidelines described in the standard EN 15461:2008+A1 [7].

Measurements were carried out with the following measuring equipment:

Containing:	Instrument:	Serial number:
Accelerometer	PCB35618	LW139344
Accelerometer	PCB356B18	LW1252375
Accelerometer	NOR1270	31567
Impact Hammer	B&K8206-003	54865

Three accelerometers and one impact hammer were used. Two triaxial accelerometer were located on the top of the track and one axial accelerometer was located to transversal sections, on the outside face of the rail head. Measurement points were located 3 meters apart, see Figure 5. The accelerometers were fixed on the rail by a magnet meanwhile an impulse force is applied to the rail head in both vertical and transverse directions. The impulse hammer was fitted with a tip of adequate rigidity to ensure a good quality measurement of the force and response of accelerometers in the frequency range of interest. The force was applied from distance 0 (related to accelerometer position) to 66 meters from the accelerometer according to EN 15610 [8].

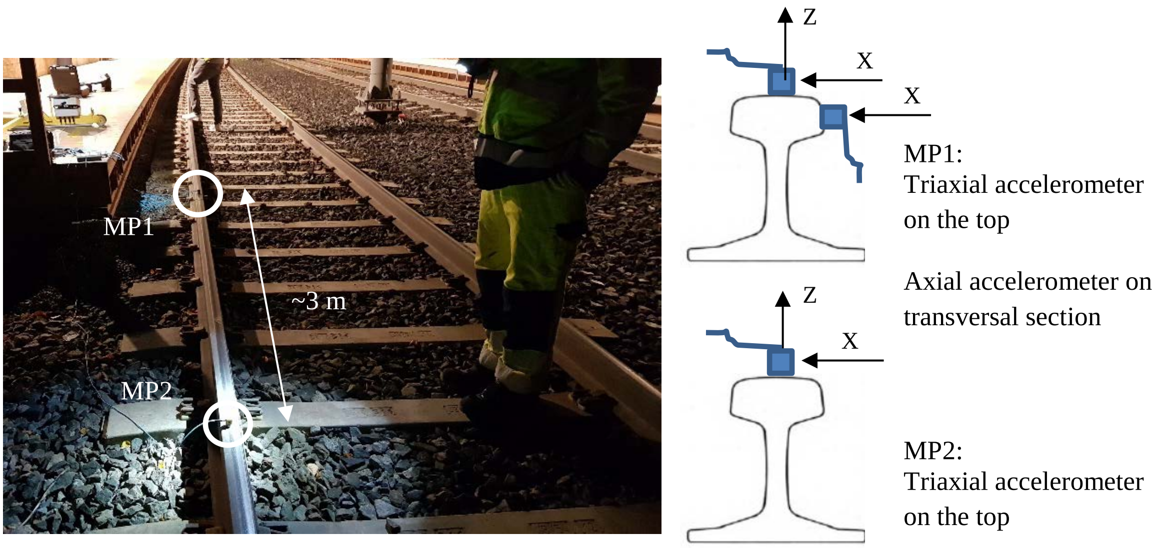

Figure 5 Position of accelerometer during measurements

4. RESULTS OF MEASUREMENTS

Figure 6 shows typical sound signals for a passing tram. The figure shows the vibration signal (up), and noise signal is shown to the bottom. Both figures correspond to the same tram.

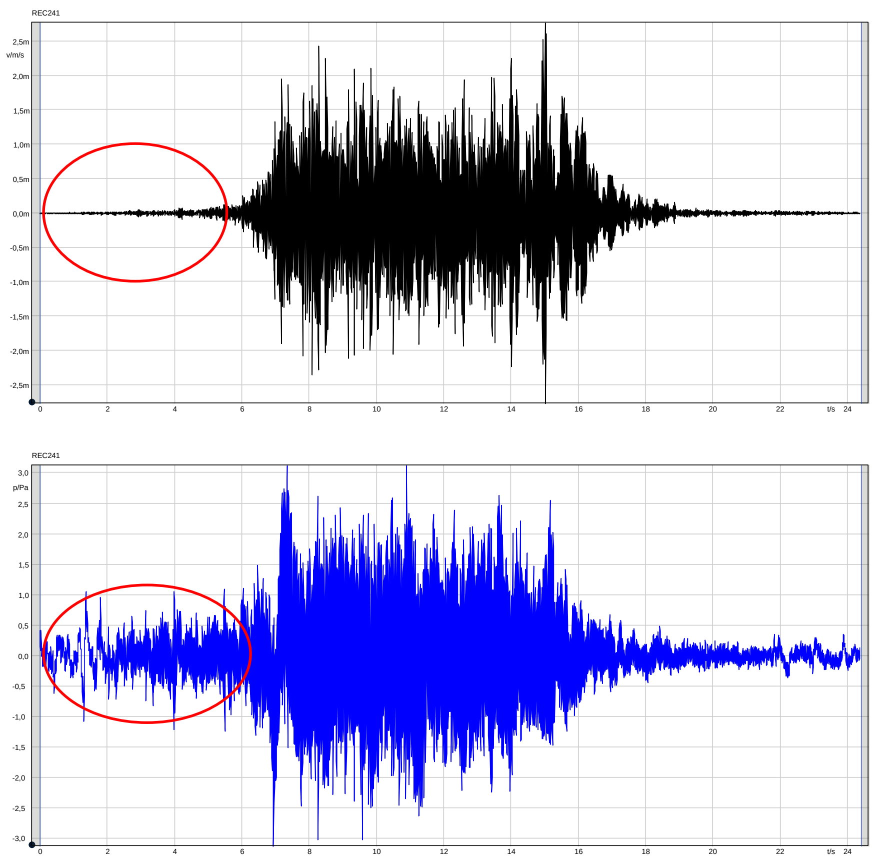

Figure 6 Typical signal for a tram passing: vibration (up), noise (down)

The vibrations propagated from tramway travel along the track and radiate noise. For this measurement, vibration levels before the tram passing in front of the measurement point are in the order of 0,01 – 0,03 m/s, which are very low. On the other hand, this small vibration creates a structural noise on the track that is in the order of 70-80 dB. Depending of the locations this sound can be heard several seconds before. For the study case presented in this paper, it was heard 6 seconds before the tram passed in from of the measurement point.

Data has been analysed from those events with noise levels over 85 dB ($L_{p,A,T} > 85$ dB). Figure 7 shows spectrum analysis for sound measurements in 2016 (left) and 2017 (right). The curves are the average of 20 measurements for each direction (inbound and outbound) and for each type of tram. Average velocities of trams were measured on 60 km/h for trams travelling out of the city and average velocity of 50 km/h for inbound direction.

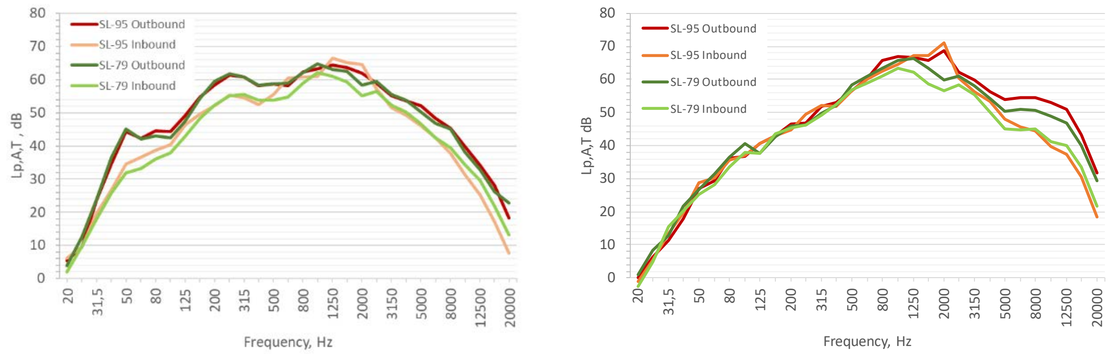

Figure 7 Spectrum analysis for sound measurements for tram: 2016 (left), 2017 (right). Average for 20 measurements

A higher amount of complaints has been received from tram noise than for metro noise. Residents describe the noise as the track sings before the tram passes by their houses. The results in 2016 show four peaks values at 50 Hz, 250 Hz, 1250 Hz and 2000 Hz. The track was renovated (it was changed the rail, sleeper and rail clips). After the renovation, the noise peak values at low frequencies were reduced. However, the rail noise continued, and residents still complain.

A new study was performed. This time only signals before the tram passing were analysed. Results are shown in Figure 9. A predominant frequency around 600 Hz was found. The same result was found for several measurements.

Analysis of track decay measurements is shown in Figure 10. This figure shows the mobility response of the track for all frequencies (horizontal axis) vs. distances (vertical axis). The track vibrates easily at frequencies between 400-600 Hz, when the track is excited in transverse directions. Track decay analysis was performed for both measurement points of tram and metro. The same results were found.

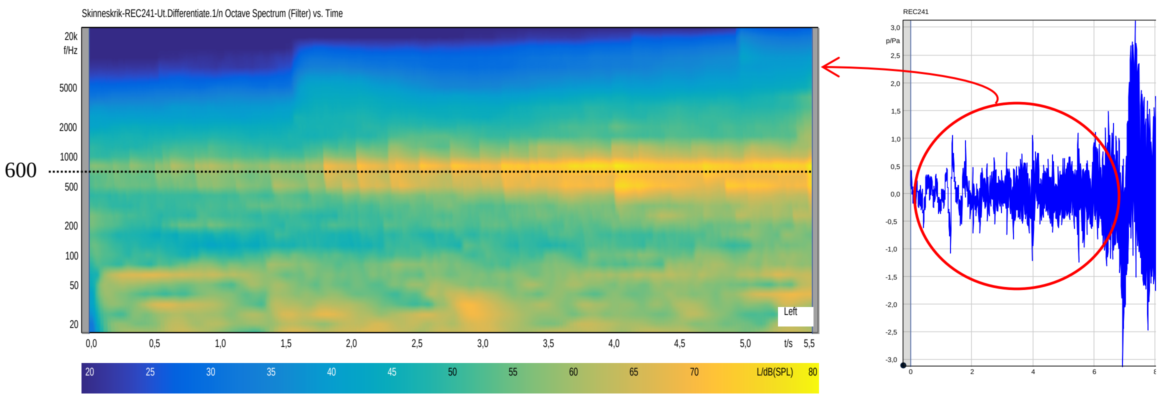

Figure 8 Spectrum analysis for sound measurements *before* a tram passing

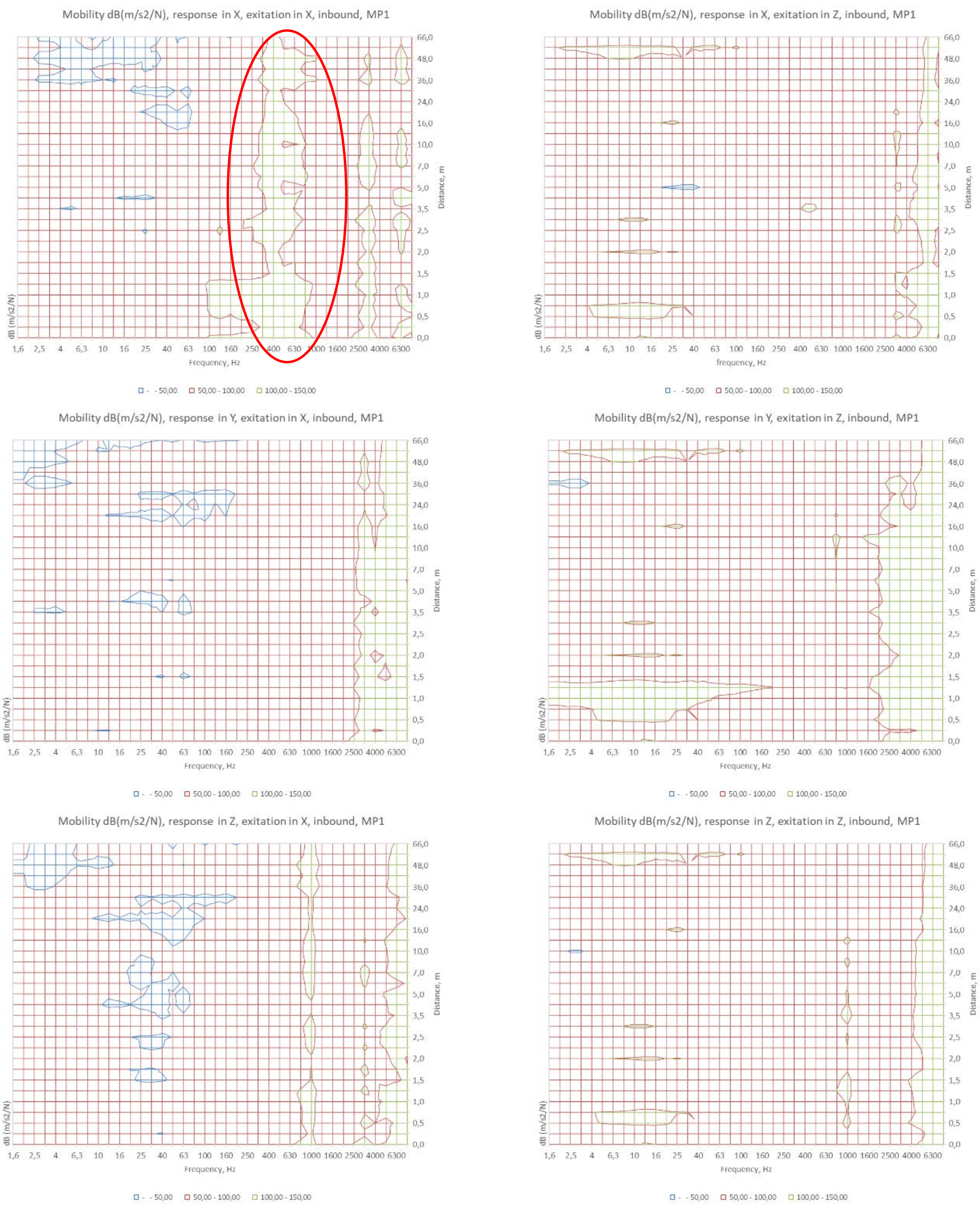

Figure 9 Mobility of the train track vs distance and frequencies. Horizontal impulse force (left), vertical impulse force (right)

5. CONCLUSIONS

Tram and metro are used as transport means in Oslo. There are still some issues about the noise developed with passing of the trains, specially rail noise radiated seconds before passing of the train. The track was renovated, but the rail noise is still a problem for residents. The present work found that rail noise has a dominant frequency around 400 – 600 Hz. The results are based on track decay analysis and detailed analysis of noise signals. Further research will study effect of new mitigation measures.

6. ACKNOWLEDGEMENTS

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