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The effect of tram track permanent way closure system on the level of noise

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Abstract

The paper deals with the analyses results of the noise level measurements carried out on the five different types of tram track permanent way closure while varying the following key parameters: load, speed and the type of the tram vehicle. The study involves the performance of the tram vehicles that are operating in the city of Zagreb. Measurement results were used for the choice of the system of the tram track permanent way closure. In addition to the noise level, the criteria included the economy of the performance and maintenance as well. The choice refers to the tram track closure system that is not separated from the road traffic, which means that the same traffic surface is shared by the road and tram vehicles. The next closure system proved to be optimal for the tram tracks in a separated lane.

1 Introduction

An impact of noise plays an important role in environmental protection. In the first place it affects people causing psychological, sociological or economic damages. As the sources of noise widely range, interdisciplinary studies should be applied. The source of noise in urban areas comes from the road, railway or air traffic [1]. So far not much attention has been paid to the ecological aspect of noise in Croatia. Systematic measurements of traffic noise are still rare. In Zagreb, the capital of Croatia the environmental aspects of noise have been studied individually in the limited areas where the locals complained about serious harmful effects of noise. The investigations carried out so far proved that the noise caused by railway traffic is lower than the one caused by road or air traffic [2]. Zagreb features heavier traffic volume than other European cities with the tram traffic as the major means of transportation. Several tram tracks in the centre of Zagreb have a traffic load of up to 15 million gross tons a year per cross section [3] with the frequency of tram vehicle running under 1 minute [4]. Therefore many locals complain about the tram noise in several places. In some areas where the effects of the noise seemed to be most harmful the Zagreb Streetcar Company Ltd. (ZET) organized the noise measurements conducted by Koncar Institute for Electrical Engineering, Laboratory for Acoustics, Vibrations and Mechanics.

The traffic noise caused by the tram vehicle in an urban area comprises the noise of the motor, noise arising from the contact between the wheel and rail, noise of the vehicle and the load, and aerodynamic noise. The noise that has no direct impact on the design of the tram track such as aerodynamic and motor noise, the noise at braking and starting off the vehicle have been deliberately neglected in this paper. The basic factors affecting the noise level of the tram traffic include the vehicle, interaction of the wheel and rail, traffic intensity and speed, climatic conditions, reflexivity and absorption of noise from other surfaces. Because of the research limitations not all basic factors have been discussed. The investigation [2] have shown that the level of noise is mostly influenced by the wheel-rail interaction. As climatic conditions, reflection and noise absorption from other surfaces can not be influenced they have not been considered in the design of tram track, geometry and closure system. In measuring the noise level we limited the study including:

- two most common types of vehicles in the Zagreb traffic,
- five different tram track permanent way closure systems,
- a measurement carried out for an individual vehicle (an average running speed being 25 km/h).

2 Description of the measurements on the field

The effect of two tram vehicle types in the noise level measurement has been studied: the type KT4 (Figure 1), the type T4 (Figure 2) by the CKD Tatra manufacturer. The mentioned vehicles take up 60% of the Zagreb Streetcar Company Ltd. vehicle park.

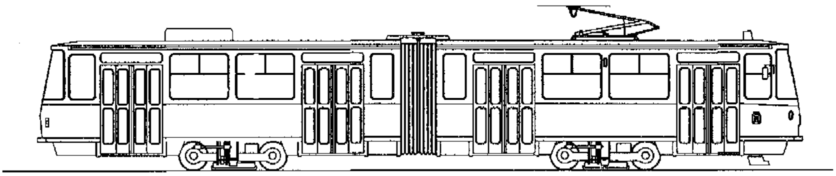

Figure 1: KT4 tram vehicle type

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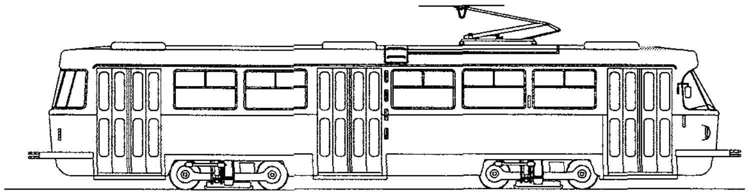

Figure 2: T4 tram vehicle type

The considered tram tracks are built on the concrete base with the same system of fastening the rails on the base. They differ only in the permanent way closure system. The measurement was carried out at five measuring places (MP). Each measuring place features a different way of tram track permanent way closure:

MP1 - tram track closure with asphalt (Fig. 3),
MP2 - tram track closure with prefabricated concrete plate (Fig. 4),
MP3 - tram track closure with crushed stone, grading is 30/60mm (Fig. 5),
MP4 - open tram track permanent way (Fig. 6),
MP5 - tram track closure with grass - grass track (Fig.7).

Figures 3 to 7 show the type of tram track permanent way closure system and the place of instruments for the noise level measurement. The researches were carried out with battery operated measuring equipment.

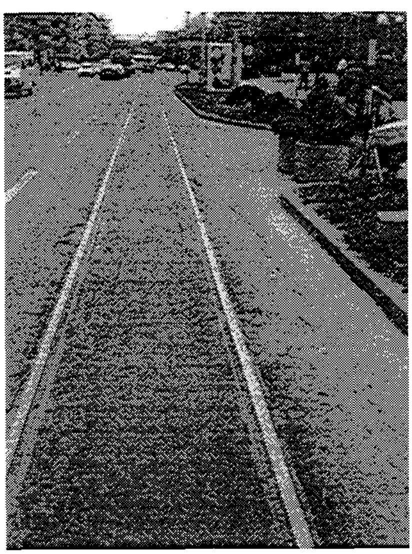

Figure 3: Savska street

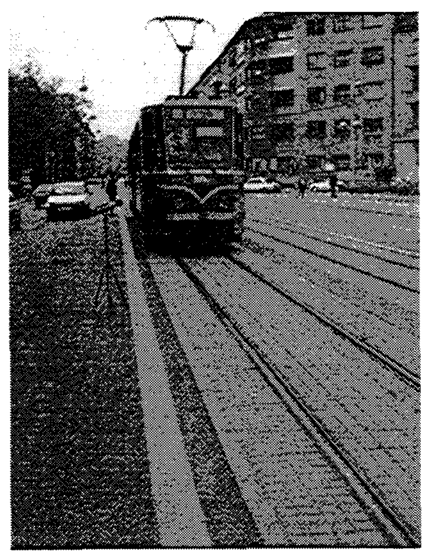

Figure 4: Subiceva street

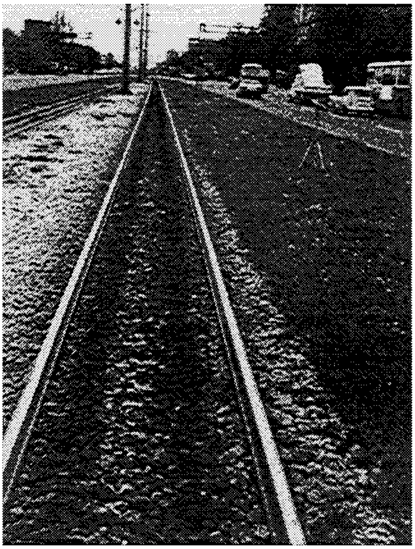

Figure 5: Dubrovnik avenue

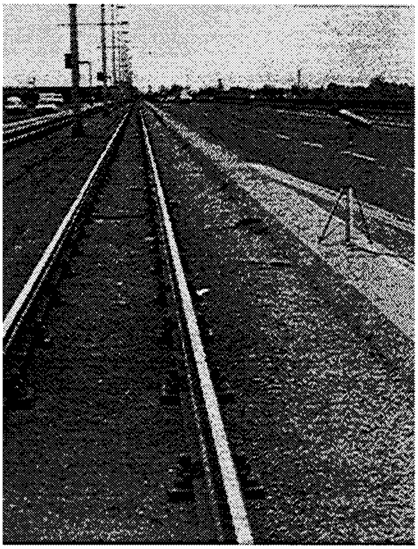

Figure 6: Horvacanska street

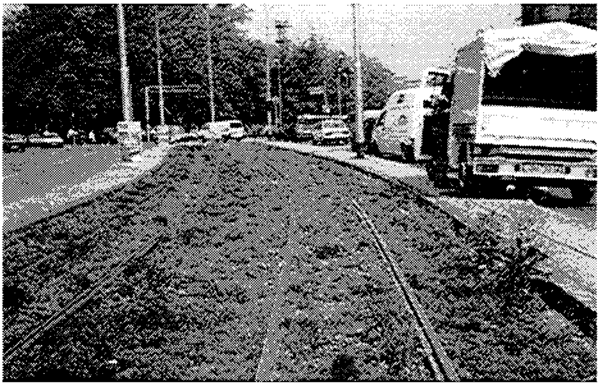

Figure 7: Subiceva street

Measuring equipment is shown in the Fig. 8 and Fig. 9 and consists of the following instruments:

- sound level meter Brüel & Kjær, type 2203, ser. number 226268
- sound level meter Brüel & Kjær, type 2203, ser. number 294550
- microphone Brüel & Kjær, type 4145, ser. number 309950
- microphone Brüel & Kjær, type 4145, ser. number 892398
- calibrator Brüel & Kjær, type 4230, ser. number 494196
- analyzer NORTRONIC, type 830, ser. number 11445
- measuring tape recorder NAGRA TI (FM), ser. number 0800168

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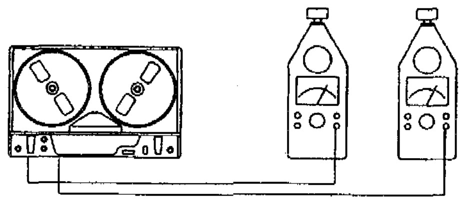

Figure 8: Measuring instruments

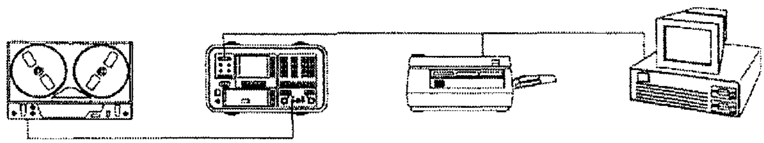

Figure 9: Instruments for data analyses

The noise level for at least five tram vehicle runs was measured at each measuring place. The noise level was recorded at the distance of 1m from the tram, at the high of 1.2m from the running surface of the rail with 2 sound level meter A and B placed at a distance of 20m. The speed of a vehicle run is determined by the measurement of the vehicle running time at a given distance.

3 Results of the measurements

The noise level measuring results during the tram run are shown in the Table 1. A characteristic survey of the noise level time alternation for each measuring place can be seen in the Figures from 10a to 10e.

Table 1. Measurement results.

Measuring place	1st measuring	2nd measuring	3rd measuring	4th measuring	5th measuring
MP1	102.1 / 88.4 T4 / 20	104.0 / 89.3 T4 / 20	99.7 / 87.1 T4 / 20	99.4 / 87.3 KT4 / 35	100.3 / 86.4 KT4 / 30
MP2	88.3 / 80.0 KT4 / 30	90.0 / 78.6 T4 / 25	93.6 / 81.1 T4 / 30	91.1 / 78.0 KT4 / 35	88.4 / 78.1 KT4 / 25
MP3	106.1 / 92.1 T4 / 30	92.3 / 81.8 T4 / 15	108.9 / 94.1 T4 / 30	105.1 / 90.7 T4 / 30	107.1 / 92.0 T4 / 25
MP4	107.5 / 96.8 T4 / 30	108.1 / 97.1 T4 / 25	108.8 / 97.9 T4 / 30	107.9 / 97.0 T4 / 25	106.3 / 96.2 T4 / 30
MP5	86.8 / 77.5 T4 / 15	81.1 / 74.7 T4 / 25	85.7 / 75.3 T4 / 25	83.6 / 74.3 T4 / 25	93.0 / 80.1 T4 / 30

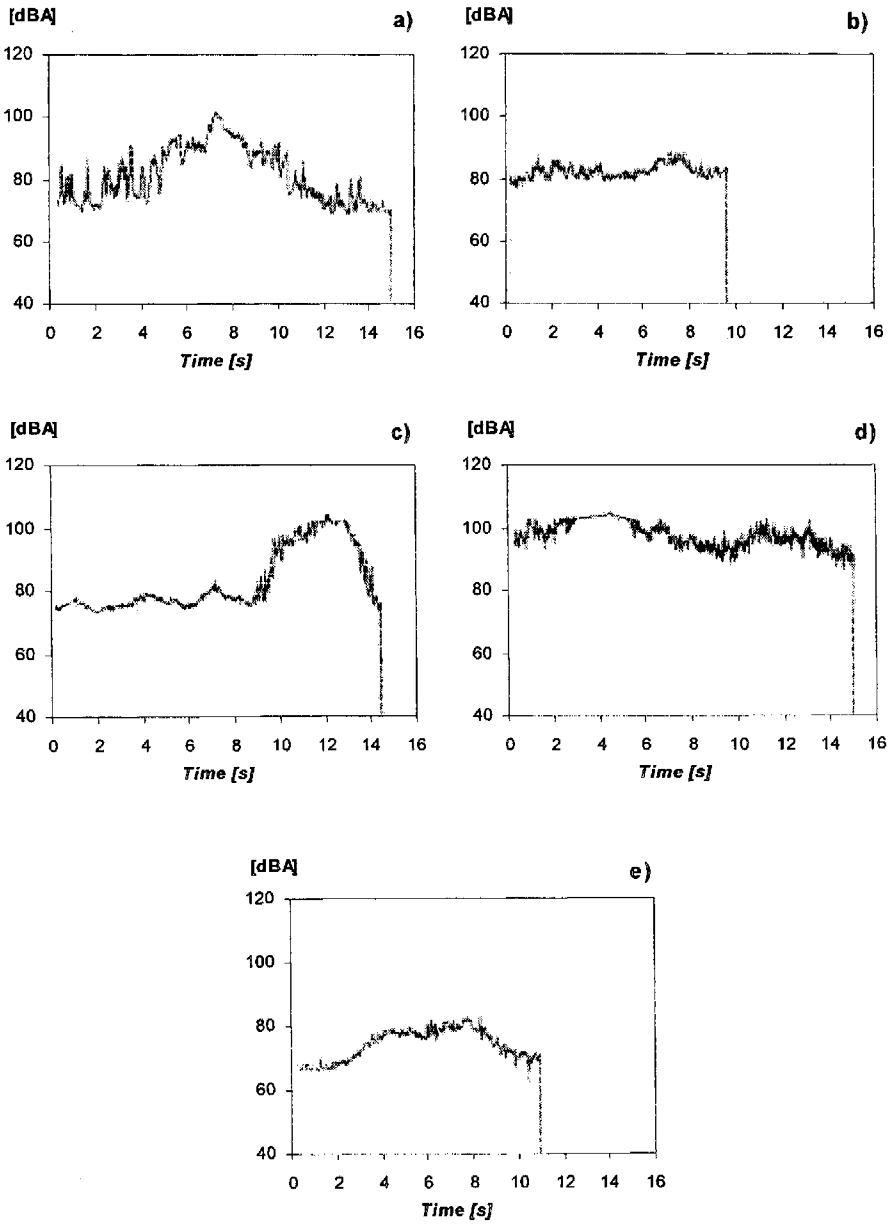

Figure 10: Characteristic review of the noise level time alternations

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As apparent in the Table 1 for each measuring place and for each vehicle run four data are given: the highest noise level L_{max}, equivalent noise level for the whole capture L_{eq}, the vehicle type and the vehicle speed. The data are shown in the following form:

$$\frac{L_{max}\,(dBA)\;/\;L_{eq}\,(dBA)}{\text{type of vehicle}\;/\;\text{vehicle speed}\,(km\,/\,h)}$$

At some measuring points an apparent increase of the noise level caused by tram run is shown, which is presented in the diagrams (Fig. 10a to 10e) of the noise level time alternations. This occurrence is most obvious at the MP3 place. In contrast to this case in the MP4 place with a 15-year-old open track the noise increase is very small. The measurement showed that the rumbling of rails could be heard much earlier before the tram arrives.
The highest noise levels were used to evaluate the condition of the permanent way. It was done so because the equivalent levels depend on the total noise level over the measuring period, that means on the proportion of tram run time and the measurement period that varies during measurements. Given data were statistically sorted out. Figure 11 shows mean value of the highest noise level for each single measuring place.

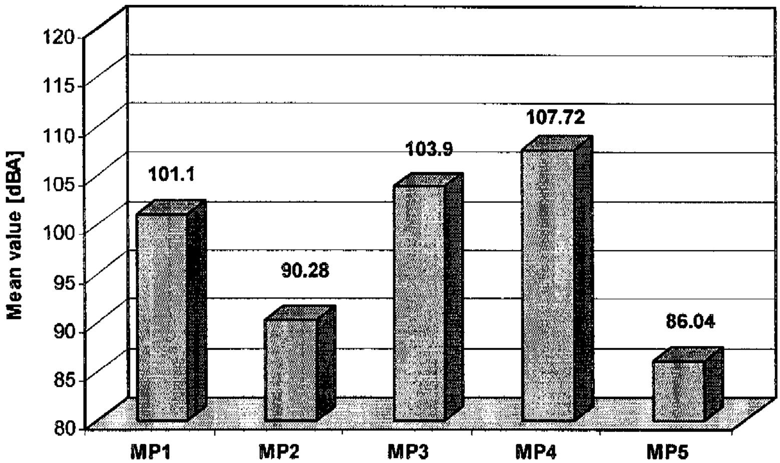

Figure 11: Mean value of the highest noise level

As shown in the Figure 11 mean value of the highest noise level is the least in the measuring place MP5 with the grass track and highest in the measuring place MP4 with the open tram track system. Mean value of the highest noise level was considered as well in dependence on the vehicle type (T4, KT4), for the

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measuring place MP1 and the measuring place MP2, Figure 12. The vehicles of the type T4 mostly run on the sections with chosen measuring places MP3, MP4 and MP5, so it was not possible to study the impact of the vehicle type on the noise level in these places. The research in the measuring places MP1 and MP2 (comparison of mean value of the noise level) shows that the lower noise level was measured during the KT4 vehicle run than during the T4 vehicle run.

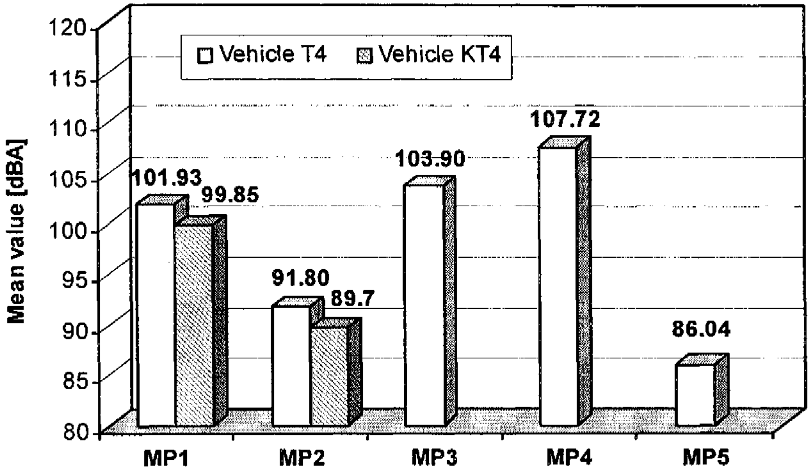

Figure 12: Mean value of the highest noise level depending on the vehicle type

4 Conclusion

Despite relatively small number of measuring places and a low number of vehicle runs, the data obtained by noise level measurements served for a choice of optimal tram track closure system in the city of Zagreb. For the tram tracks bedded into the pavement construction, which means that the same traffic surface is shared by the road and tram vehicles, it was decided to perform the tram track closure with prefabricated concrete slabs, as already shown in Figure 4. Such a choice was made not only due to a lower noise level, but also because of the lower maintenance expenses.

With the tram tracks separated from the pavements, that means where the tram track is in a separate lane, the tram track closure with crushed stone is recommended (Fig. 5). However, the measurements found the lower noise level in the grass track. Grass tracks are very attractive and environmentally friendly but their maintenance costs are much higher than the tram track closure with crushed stone. Apart from it, grass tracks proved to be pretty inaccessible in the rainy period. As the age of the vehicles ranges from 15 to 40 years in the case of the tram breakdown the truck crane would have many difficulties in taking the broken vehicles back to tram-depot, as it usually happens in Zagreb. This procedure proved to be much simpler with the tram tracks closure with crushed stone than with grass (grass tracks).

Discussion

It is common knowledge that there are two primary sources of noise: vehicle motors and the wheel-rail interaction. Previous investigations carried out to reduce the noise level in the tram traffic of the city of Zagreb showed the necessity and the way of conducting extensive research. The noise level investigation project encompasses two main parts:

(a) selection of track closure,
(b) selection of relevant vehicle type (without involving the performance of the vehicles with regard to noise level abatement).

In the study of the case (a) longer permanent way sections should be considered under the condition of uniform running speeds of uniform vehicles. Such an approach should yield precise data for comparison of different closure types during a certain exploitation time. A measuring microphone is supposed to travel in a vehicle. One possibility is to place it between wheels where the effects are most notable. Such measuring concept could ensure a network supply of the equipment and simultaneous data writing on the diskette as well as the possibility of two-channel measurement (e.g. under motor driven vehicle and under trailer).
In the study under (b) the research conducted to get precise data should be carried out on the testing track section. A change of noise level in time during the tram run at various speeds should be measured here. A great advantage of such a measurement is a network supply that means a direct analysis on the terrain as well as the possibility of data saving on the diskette and the two-channel measurement (on the both sides of the vehicle).
The measurement results could serve for the ranging of the noise source. It could lead to dynamic results to solve the noise level problems in the urban areas with heavy volume traffic. In this manner an intervention in a substitution of the vehicle type, in the tram closure or in the limiting the running speed in these areas could be undertaken. With the rapid grow of the city such researches are of the utmost importance.

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