The impact of tram track fastening systems on noise level

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Abstract

The paper presents the results of measurements of noise levels caused by traffic (tram and road traffic) in Drziceva Street in Zagreb (Croatia). Noise level measurements were conducted in cooperation with the City Office for Construction and the Zagreb Streetcar Company (ZET). The tram track in Drziceva Street represents one of the main connecting routes between the northern and southern parts of the city (a length of approximately 4km). The tram tracks are in a separate traffic area. They have been laid on a continuous concrete base and covered with crushed stone. The greater part of the tram track was constructed using the Zg 3/2 system (a direct elastic fastening system), whereas the remainder of the tram track was constructed using the DEPP system (indirect elastic fastening system). Noise level measurements were conducted at two measuring points (one measuring point was chosen for each of the fastening systems). Short-term noise level measurements were executed: two measurements in the daytime period (morning and afternoon), one measurement in the evening and one in the nighttime period. Speed and tram types were taken into consideration during result analysis, as well as geometrical irregularities of the rail running surfaces, the number and category of road vehicles and noise level protection measures already implemented. The conducted measurements have served to compare tram track fastening systems with noise level propagation when trams communicate the route. The results of the research have been of assistance in defining the extent of tram impact on noise level increase (dependent on type and speed of these) in comparison with that of road vehicles communicating the very same route.
Keywords: tram track, fastening system, tram vehicles, road vehicles, noise level measurements.

1 Introduction

The research works have shown that the increased noise level is one of major reasons for the reduced quality of living. The noise has a negative impact on psycho-physical characteristics and concentration of people; it also causes disturbances in communication etc. A number of experts of various professions are dealing with this problem in the EU countries, and other developed countries in the world. The measures that would improve the environment condition and, simultaneously, the conditions of living and working of the people, are the subject of numerous professional and scientific projects.

In Croatia, sufficient attention is not paid to the noise as an ecological issue, especially regarding urban environment. Until now, noise protection has been applied along the motorways only. The ever increasing complaints of citizens who live and work close to the roads with high traffic load, have moved certain municipal authorities to initiate the procedures for reducing the noise level , e.g. in Zagreb, [1].

The Municipal Construction Office of the city of Zagreb has ordered to the Transportation Department of the Faculty of Civil Engineering in Zagreb to prepare a Study with the aim of analyzing actual condition and proposing the measures to be taken at the locations that were mostly complained by the citizens because of the high noise level. It should be noted here that at these locations, the increased noise level is most frequently due to the road and track vehicles traffic (tram, railway) that represent the skeleton of the public city transport.

This paper represents only a small segment. The results indicated in this paper refer to one location only. It is Drziceva Street, and the emphasis is given to the tram traffic which is one of most important generators of the increased noise level – see diagrams in Chapter 3.

2 The location description – Drziceva Street

Drziceva Street is one of major routs between the northern and southern part of the town. It consists of two carriageways, one for each driving direction, and with three lanes each. The tram line is in the middle between the two carriageways, fig. 1.

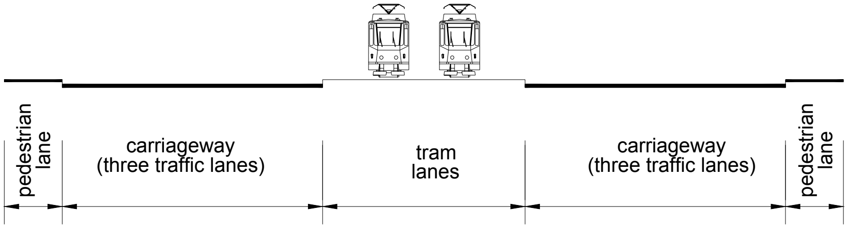

Figure 1: Drziceva Street – Cross section.

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This street has an extremely high total traffic intensity. The equivalent noise level values measured during the day, in the evening and at night are far higher than allowed values, figures 2 and 3. The figures show the measuring results obtained at two locations of Drziceva Street.

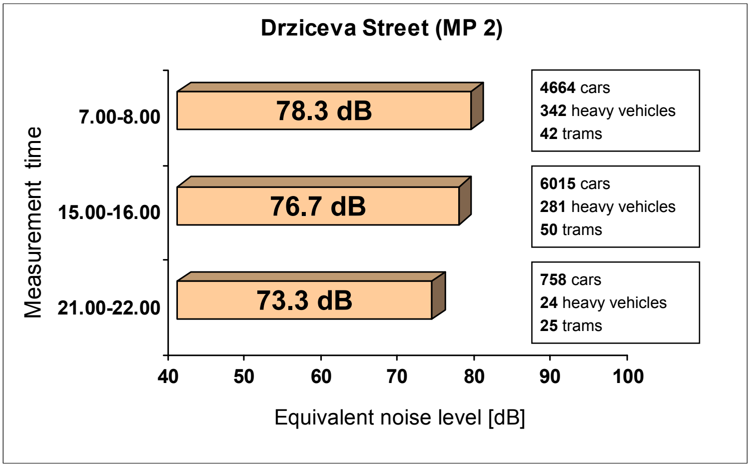

Figure 2: Noise level depending on the traffic intensity (MP 1).

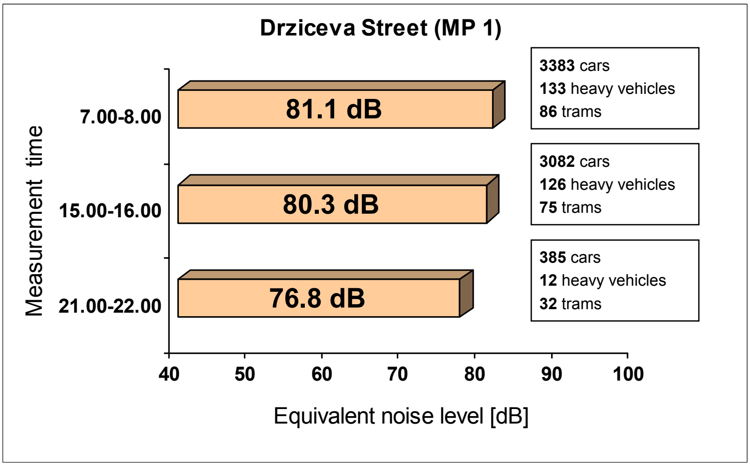

Figure 3: Noise level depending on the traffic intensity (MP 2).

It is obvious that the measured noise level values exceed those allowed in Croatia for the period day and evening (65 dB) but for the night period (55 dB) as well, [2]. The equivalent noise level dependence on the traffic intensity can also be seen. It can be noted that the passenger cars traffic and the heavy vehicles traffic is very high, not only during the day but in the evening as well. Yet, the tram traffic has got the largest impact on the maximum noise level. Actually, the noise peak levels appear just due to the tram passage as it can be seen on the obtained noise level measurement diagrams. This fact initiated further investigation of the tram traffic impact on the noise level. The tram traffic in the town of Zagreb is significantly higher than in other European towns in which the tram traffic represents the skeleton of the public municipal transport. Actually, certain tram lines in the center of the town have an annual traffic volume of even up to 15 million gross tones per section, with the tram passage frequency of less than 1 minute, [3, 4]. Thus it is no wonder that the disturbances described by the citizens of the residential houses located close to Drziceva Street were alarming.

The essential factors affecting the tram traffic noise level are: tram, wheel and rail interaction, traffic intensity and speed, weather conditions, and noise reflection and absorption by other surfaces. For the purpose of narrowing the scope of investigation, all these major factors have not been analyzed individually. The wheel-rail interaction has the highest impact on the noise level, in particular, the way of fastening the track to the base. For this purpose, the investigation was directed only to the consideration of the upper tram track structure which is most responsible for the reduction of noise and vibration spreading on the neighboring structures, [5].

The upper tram track structure means the type of fastening the rails to the base, and the way of closing the track. The impact of the tram track closing is not considered in detail in this paper since this part was treated by the Study on the optimal tram track closing prepared by the Faculty of Civil Engineering for the requirements of ZET (Zagreb Streetcar Company Ltd.). It was found that the best way for the tram tracks that are structurally and physically separated from the road structure, i.e. placed in a separate body, was to be covered with crushed stone, regarding both – the cost of construction, and maintenance costs, which was the case in Drziceva Street, [6]. Accordingly, the study was focused only on the impact of the tram track fastening system on the noise level due to the trams traffic.

3 Description of the measurements on the field

During the investigation, two fastening systems of tram track have been considered: DEPP system (Double elastic fastening system), and the ZG 3/2 system, fig. 4.

Both fastening systems are used for the tracks constructed on the continuous concrete base but they provide different elasticity at the fixing point. The DEPP system belongs to a group of indirect elastic fastenings, while the ZG 3/2 system belongs to a group of direct elastic fastenings. With the DEPP system, two neoprene rail pads are inserted between the rail foot and the concrete base, and the stiffness of the entire fixing point reaches 40MN/m. The ZG 3/2 system has only one pad between the rail foot and the concrete base, and the stiffness of its fixing point amounts to 140MN/m. The rest of the space to the concrete base is filled with a leveling layer. In order to make the systems comparable regarding the noise level, it is important that all elements within the fixing point perform their functions. A condition of a permanent contact between the elements in vertical direction should be fulfilled (vossloh clip-rail-rail pad-concrete base) with permanent vertical stress along the elements contact surfaces. That is why the measurements at the subject locations were carried out within a short period (30 days) after completion of the track reconstruction.

These measurements were carried out with the following measuring equipment:

- noise measuring instrument Bruel&Kjær, type 2260, ser. number 2426409
- noise level calibrator Bruel & Kjær, type 4231, ser. number 2432247
- microphone Bruel & Kjær, type 4188, ser. number 2430077
- microphone wind protection
- aluminum telescopic tripod

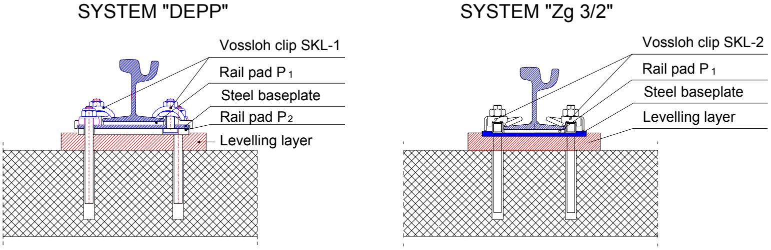

Figure 4: Fastening systems of tram tracks in Zagreb.

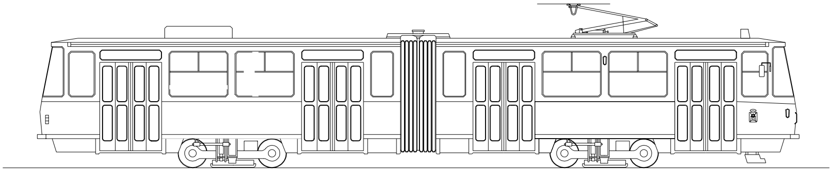

Figure 5: Tram type KT4.

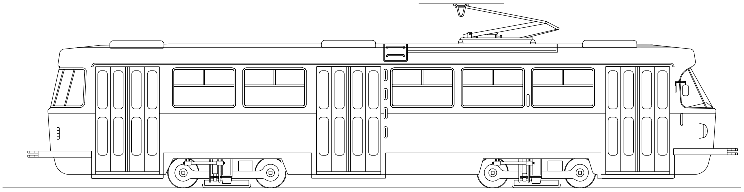

Figure 6: Tram type T4.

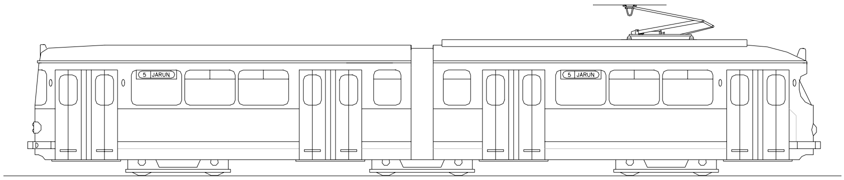

Figure 7: Tram type GT 6.

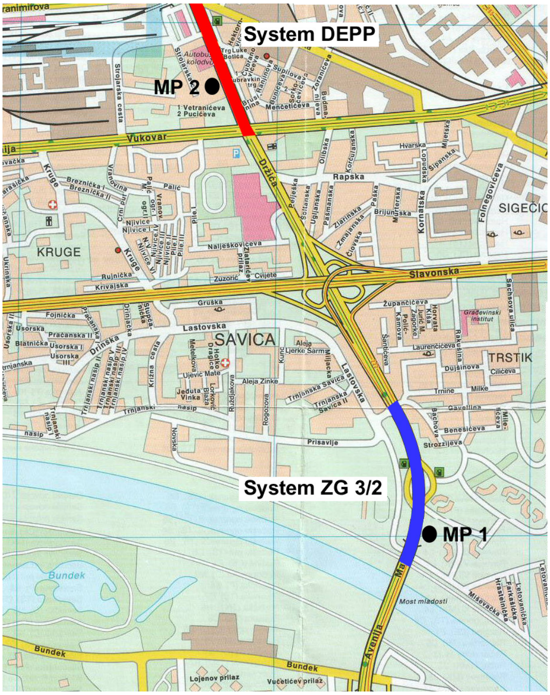

Figure 8: Indications of measuring points (MP) at Drziceva Street.

The impact of three types of trams was observed: type KT4 (fig. 5), type T 4 (fig. 6), both manufactured by “CKD Tatra” and type GT 6 (fig. 7) manufactured by “Düwag” which, among others, are in service at the observed location. These types of trams cover about 75% of the total number of trams in the possession of ZET (Zagreb Streetcar Company Ltd.).

The measuring was carried out at two measuring points (MP), one MP for each type of fastening system, fig. 8. The noise level measuring instrument was installed 1 meter away from the tram track, at the level of 1.2m from the running surface of the rail, fig. 9. The speed of trams traffic was measured by recording the time of a tram passage between two fixed points (lighting pillars). All measurements were carried out on a smooth running surface of the rail, and under favorable weather conditions, and temperature 8 to 15 °C, depending on the period of the day, and at the low wind velocity of 1 to 3m/s.

Figure 9: Position of instruments during measuring.

Table 1: Noise level measuring results.

Noise level [dB] / Time period	Measuring point 1			Measuring point 2		
	L_{eq}	L_{max}	L_{min}	L_{eq}	L_{max}	L_{min}
7.00 – 8.00	81.1	96.5	63.6	78.3	92.8	54.4
15.00 – 16.00	80.3	97.8	66.9	76.7	93.7	57.2
21.00 – 22.00	76.8	90.2	62.3	73.3	87.1	52.4

The noise level short time measurements (15 minutes) were carried out at both measuring points, two measurements during the day time (morning and afternoon), and one measurement in the evening and at night respectively. Since the noise level values obtained at the first measuring point during the night were lower than those obtained in the afternoon and in the evening, the night measurement at the measuring point 2 was not performed.

In order to obtain a complete image of the impact of traffic means (not only trams but the road vehicles as well – especially heavy vehicles) on the noise level, shooting of the traffic load was carried out at both measuring points. The traffic shooting was performed by means of a digital video camera (type TRV 60E – SONY DCR) installed on a telescopic stand at the level of 1.2m. One hour traffic shooting was carried out at both measuring points during the day (in the morning and in the afternoon), and in the evening, see figures 2 and 3.

4 The results of measurement

The measurement results of the noise level caused by the passage of trams are presented in the table 1. Three data are provided for each measuring point:

maximum noise level (L_{max}), equivalent noise level (L_{eq}), and minimum noise level (L_{min}). Maximum noise levels (the peaks) appeared after the passage of trams, which can be seen in the noise level time diagrams, figures 10 and 11.

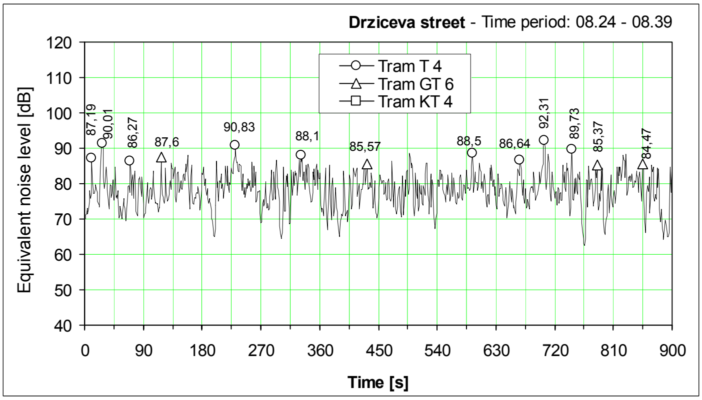

Figure 10: Characteristic indication of the noise level time change (MP1).

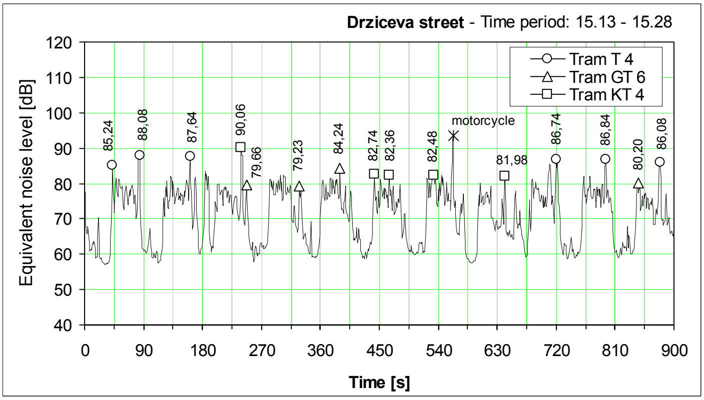

Figure 11: Characteristic indication of the noise level time change (MP2).

It is obvious from the noise level time change diagram that the noise level increases due to the tram passages. Each tram passage increases the noise level above 80dB, and not infrequently to the level of 90dB and above. The tram passage frequency is 1 to 2 minutes. Within a short period of time, there are sudden oscillations in the noise levels with negative consequences for people. The trams traffic speed measurements indicate that the noise level depends significantly on the tram traffic speed. By reducing the trams speed, the noise levels were reduced, in some cases, even by 8dB. For comparison of the systems for fastening tram tracks to the base, the maximum noise levels were used since the equivalent values depend on the total noise level in the period of measuring, and they also contain the noise caused by other traffic participants. The obtained maximum measured values have been statistically analyzed, and the average value of maximum noise levels for each measuring point separately is shown in figure 12.

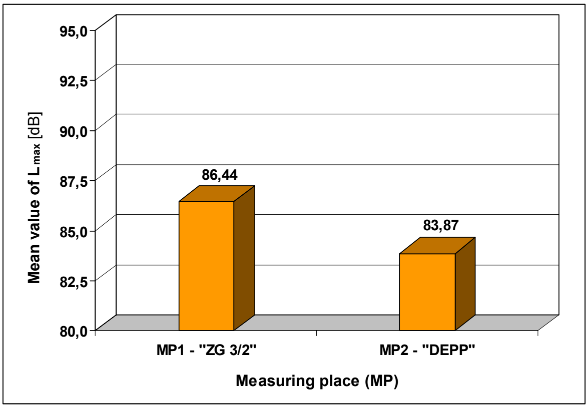

Figure 12: Mean value of maximum noise levels.

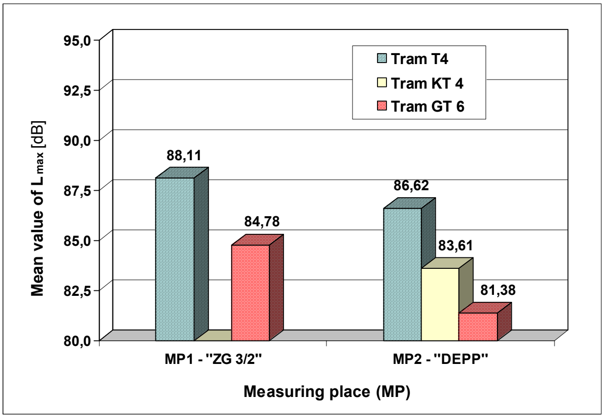

Figure 13: Mean value of maximum noise levels depending on the tram type.

As it can be seen in the Figure, the average value of maximum noise levels at the measuring point 2 with the installed DEPP system is lower by up to 3dB, in comparison with the measuring point 1, where the system ZG 3/2 is applied. Along with the comparison of the tram track fastening systems, the average values of maximum noise levels have also been compared, depending on the tram type (KT 4, T4 and GT 6), which circulate along the tram line with the said systems, fig. 13.

The comparison of maximum noise levels mean values indicates that the passage of GT 6 tram type causes the lowest increase of the noise level in both cases of the tram track fastening systems. The tram T4 type passage causes the highest increase of the noise level – even by 5dB in comparison with the passage of other tram types.

5 Conclusions

The noise level measurements carried out within the larger project, only a part of which is presented in this paper, have served for the comparison of the tram track fastening systems. Since the results of measurements have shown that a double-elastic system of fastening, such as DEPP system, is more suitable with regard to the reduced spreading of noise but to the reduced spreading of vibrations on the people and the surrounding structures as well, the same was recommended to be used in the city of Zagreb. This double-elastic fastening system is also recommended by the EU Commission, especially in the case of tracks installed on a concrete base, as it is the case with the tram tracks in Zagreb.

It should be noted here that the type of trams and their speed have a great impact on the noise level as well. It was proved by the measurements that the speeds lower than 20km/h cause the noise levels that are by 3 to 4dB lower than those caused by the tram speeds higher than 20km/h. The highest noise level increase was caused by a tram type T4 (manufactured by CKD – Tatra) having an age of about 30 years, which are out-of-date, and which do not deserve to undergo a general overhauling. It was recommended to substitute the said tram type with the technologically more suitable trams which exist within the ZET rolling stock or, if it is possible, to purchase new trams. Consequently, at the beginning of 2004 ZET ordered 72 new trams (CROTRAM) to be manufactured by the Croatian producers KONCAR and GREDELJ, with a purpose of increasing the comfort of passengers, and decreasing the spreading of noise and vibrations caused by a tram passage.

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