Investigation of noise radiated by traffic at the intersection of roads

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Noise related problems are increasing with detrimental effects on human health and quality of life. The regulations and laws of European Union and Lithuania emphasize the importance of noise reduction, the necessity to collect and analyze information related to traffic flow, the development of traffic flow mathematical models. Measurements were performed of traffic noise at the road signalized intersection in Kaunas suburb. At this location traffic flow rates are high and noise is dominated by low and very low frequencies. The developed methodology can be used to estimate traffic noise levels in a city and country districts using data provided by the automated traffic flow registration system.

Traffic noise, intersection, road

Introduction

Increasing number of vehicles considerably reinforces environmental pollution. The transport systems in Lithuania are dominated by relatively old vehicles that are generated high levels of traffic noise. The number of transport type vehicles in Lithuania is constantly increasing. Traffic flow in cities, especially in city centres and at the arterial roads in suburb, are very intensive. The scientific studies showed that the average values of $L_{pA,eq}$ reached 72,9–79,4 dBA in the biggest cities of Lithuania (Jotautiene et. al., 2011). This is significantly large than the typical noise levels $L_{pA,eq}$ = 65 dBA in European countries (Affenzelen et. al., 2005.).

The frequency composition of environmental noise plays important role in assessing the effects of noise on humans (Directive 2002/49/EC, 2002). The low and very low frequencies contributions need to be included in assessing the qualitative effects of noise (Leonardi, 2005; De Coensel et. al., 2006). Low frequency sound is defined in the range of 20-200 Hz. Very low frequency is often defined as sound composed of waves in the frequency range of 0,1-20 Hz. Low and very low frequency sound in various industrial complexes, transportation systems, etc., causes special problems due to the capability to propagate long distances. The various noise control devices installed for noise reduction are not very effective at these frequencies.

The A-weighted measurement scale is the most appropriate procedure to account for the human hearing sensitivity at different frequencies. An international standard for the measurement of low and very low sound introduced A weighting curve (G-weighting) based on perception data. Using this approach, approximate loudness contours are developed and used for practical applications (Jotautiene et. al., 2011; Lian-Feng et. al., 2005).

The object of research – investigation of traffic noise at the intersections roads in Kaunas suburb.

Methods of investigation

The acoustic noise emission from traffic flow is estimated according to standard LST ISO 1996–1–2008 „Acoustics. - Description and measurement of environmental noise“ and HN 33–1–2011 „Acoustic noise. Limit Values of Noise in Residential and Public Buildings and Their Environment” specified by $L_{A,eqT}$ (equivalent continuous A-weighted sound pressure level over duration T) (HN 33, 2011).

The A-weighted noise levels in dB(A) were measured using noise level meter ‘CEL - 440’. Measuring time is not limit. The data can be stored in an integrated device. The device measured noise data stores in the memory. It can be displayed at any time (after a measurement time or during measurement) without interrupting the measurement process, and without loss of stored data in the device memory. After the measurement the data are transferred to the personal computer, using special computer software CEL. The data are processed and analyzed by Excel software package. Also the data from the noise level meter can be derived to printer. Measurements were performed when wind speed was less than 5 m/s. Noise was measured at a distance 1.5 m from the ground and more than 3.5 m from the walls of the surrounding buildings as recommended by the Lithuanian standard LST ISO 1996-1-2008.

Measured parameters are as follows:

- Momentary noise level;
- Equivalent noise level (L_{eq});
- Maximum noise level (L_{max});

The measurements were performed at the distance of 7,5; 15; 30 m on perpendicular direction to the road line in accordance to requirements and recommendation (LST ISO 1996–1–2008, 2008; Ersoy et. al., 2011, Environmental Noise Measurement, 2004) (see Fig. 1).

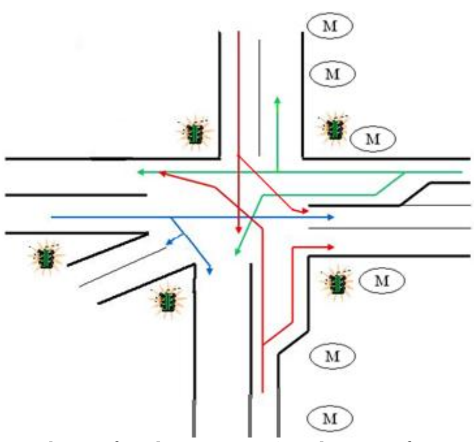

Fig. 1 Schema of road intersection (M – location of measurements).
1 pav. *Kelių sankryžos schema (M- matavimo taškai)*

The measurement locations selected at 50 m or at a greater distance from the bus station. To avoid mistakes, the measurements carried out when measurer person was a half meter from the microphone.

The measurements for estimation noise at intersection were carried out at the intersections in the area of roads near the camp Lithuanian University of Agriculture (Ringaudai village). This type intersection was selected for measurements, because traffic flow is very intensive and the low velocity (till 50 km/h) was observed. Measurements of traffic noise levels were performed only at the green light traffic cycles and at peak hours in the morning. Evolution of the L_{Aeq}, L_{max} levels was recorded during the green traffic signal cycle (t=20 s). It has been established that the A-weighted measurement scale is the most appropriate procedure to account for the human hearing sensitivity at different frequencies. Using this approach, approximate loudness contours were developed that can be used for practical applications in assessing noise criteria. Traffic noise data at the intersection has been analysed using the statistical methods described in the scientific literature (Abo-qudais et. al., 2007; Yamamoto, 2010).

Results and discussion

The measured data are presented in Fig. 2,3,4 and 5 of the intersection. It has been noted, the L_{Aeq}, L_{max} levels was recorded during the green traffic signal cycle. It can be seen that L_{Aeq}, L_{max} levels almost continuously decrease till the end of the green traffic signal cycle. At the beginning of the green traffic signal cycle, the measured maximum noise level is 91.9 dB (see Fig. 2) and at the end of the cycle minimum noise level is 48,9 dB. The maximum noise level was observed at intersection when the heavy vehicle were strated at green signal. This was a separate case. It was found that at the intersections, the L_{Aeq} levels almost continuously decrease from 70-86 dB(A) (Fig. 5). Interrupted traffic flow generates higher noise levels due to acceleration (hot-starts) of the vehicles. The intersections are empty of vehicles after 10 s and the background noise is dominant.

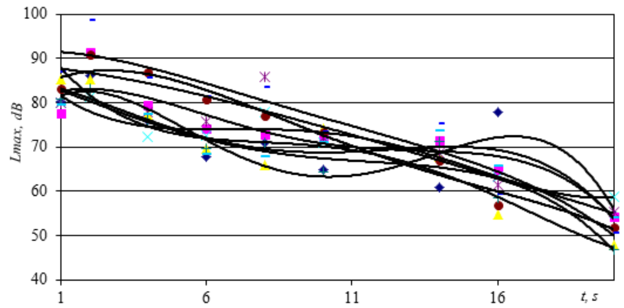

Fig. 2 Variation of L_{max} levels at the intersections of 7.5 m from the road lane.

2 pav. *L_{max} lygių kitimas kelių sankryžoje 7,5 m atstumu nuo kelio juostos*

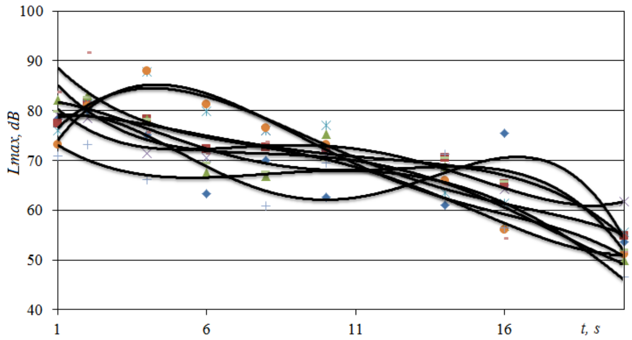

Fig. 3 Variation of L_{max} levels at the intersections of 15 m from the road lane.

3 pav. *L_{max} lygių kitimas kelių sankryžoje 15 m atstumu nuo kelio juostos*

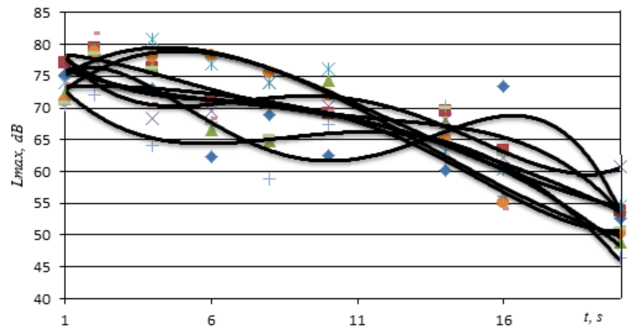

Fig. 4 Variation of L_{max} levels at the intersections of 30 from the road lane.

4 pav. *L_{max} lygių kitimas kelių sankryžoje 30 m atstumu nuo kelio juostos*

The experimental noise spectra levels shows that low-frequency (20-200 Hz) noise is dominated in the traffic flow radiated noise (see Fig. 5). Due the diffraction effects the low and very low frequency acoustic sound is travelling over longer distances and is slightly reduced as a vehicle noise is quite intensive (about 80-87 dB). From the acoustic noise measurement data it can see that acoustic noise levels exceeding permissible values even in the most remote points from the road area.

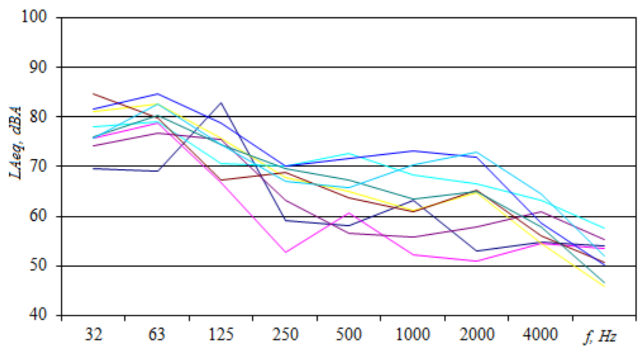

Fig. 5 Variation of L_{Aeq} levels at the intersections.

5 pav. *L_{Aeq} lygių kitimas kelių sankryžoje*

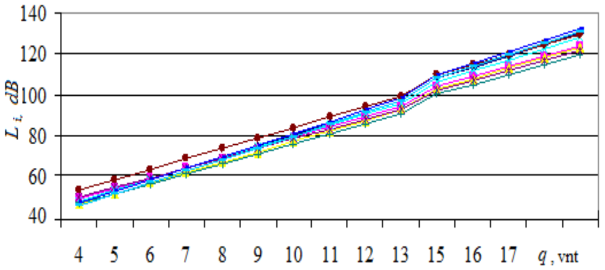

Fig. 6 Results of the composed regression model of noise L_i and traffic flow q.
6 pav. *Sudaryto triukšmo L_i ir eismo srauto q regresinio modelio rezultatai*

To obtain the relationship between traffic flow intensity q and noise levels, a regressive model is constructed (see Fig.6) (Abo-qudais et al., 2007; Jonasson, 2007; Source modeling of road vehicles, 2014). According to the results of Pearson criterion (93.27-99.49 %), the correlation between the flow intensity and noise is high and a null hypothesis H_0 (data are correlated) is accepted. Having defined the correlation, a regressive model is implemented, and data distribution is represented by regression equation. Hypotheses that regression equation factor is equal to 0 are rejected. The coefficient of variation R_2 is used to evaluate the dispersion from the average, which can provide information on regression between the different variables. Based on the obtained results, dispersion analysis is also performed and the dominant independent variables are included in the regression equations. If the conditions of direct regression and model adequacy are acceptable, predictions of traffic flow and noise are performed.

To evaluate interdependence of noise level L_i and traffic flow intensity q, H_0 hypothesis of equality of the averages is verified. However, due to nonconformity of data to some minimum requirements, one of which is that data need to be distributed according to Gauss (normal) distribution, Student distribution is not applicable. The analysis and data indicate that noise level is directly proportional to the intensity of traffic flow. It is why the average dispersion and reliable intervals can be evaluated. The results are graphically presented in fig. 6. This verification (95% CI) indicated that the developed models were found to have good prediction capability. This methodology allows to estimate simultaneously noise levels in a city according to data provided by the automated traffic flow registration system. The information is necessary for environmental transport management systems.

Conclusions

1. It was found that at the intersections, the L_{Aeq} levels almost continuously decrease from 80-87 dB(A) to 50 dB(A) till the end of the green traffic signal cycle, i.e. noise generated by ”hot starts“ dominates. The intersections were empty of vehicles after 10-15 s and the background noise was dominant. Thus, the aim is to minimize interrupted and to maximize continuous intervals of traffic flow in order to reduce noise levels in suburb environment.

2. The measured and calculated noise level L_{Aeq} analysis indicate that means of noise levels during the green signals are not statistically different. The verification indicated that the developed models were found to have good prediction capability.

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Eismo srautų sukelto triukšmo kelių sankryžoje tyrimai

Summary

Dėmesys triukšmo sukeliamom problemom auga visame pasaulyje dėl žalingo poveikio sveikatai ir gyvenimo kokybei. Europos Sąjungos ir Lietuvos teisės aktai ir įstatymai pabrėžia triukšmo sumažinimo svarbą, būtinybę rinkti ir analizuoti informaciją triukšmui įvertinti, susijusią su eismo srautais, eismo srautų matematinių modelių kūrimu ir jų įgyvendinimu. Transporto sukeliamo triukšmo matavimai atlikti Kauno miesto ir jo priemiesčio gatvių sankryžose. Šioje vietoje eismo srautų lygis yra aukštas ir dominuoja žemų ir labai žemų dažnių triukšmas. Sukurta metodika gali būti naudojama įvertinti eismo triukšmo lygius mieste ir šalies rajonuose naudojant duomenis gautų iš automatizuotų eismo srautų registracijos sistemų.

Transporto triukšmas, kelių sankryža, matematinis modelis

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