NOISE CONTROL AT DESIGN AND CONSTRUCTION OF LINEAR TRANSPORTATION OBJECTS

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Abstract
The features of design and construction of noise protection for the linear objects of transportation complex (such as long straight roads) will be given. The steps of design process will be described and the methods of selection of noise protection means will be proposed. Some special features of sound propagation through natural and human-made objects will be presented.

INTRODUCTION

A distinct difference between the construction industry and other industries is that construction is, in the majority of cases, a temporary activity. Even very large roads are under construction in a particular area for only a reasonably short time period, seldom more than two years. As the construction project progresses, the noise from such a project changes as the different phases of the construction are undertaken. Thus, rather than being a continuous problem, construction noise is always a temporary site-specific problem. As such, there are many factors that contribute to the potential impacts due to construction noise, including the location of sensitive receptors, the type or phase of construction, the combination of equipment used, the site layout, and the construction methods employed. The noise created by construction equipment will vary greatly during a project, depending on such factors as the type of equipment, the specific equipment models, the operation being performed, the care employed by equipment operators and the condition of the equipment being used.

The equivalent sound level (L_{eq}) as it relates to construction activity depends on several factors including machine power, the manner of operation and the amount of time the equipment is operated over a given time period. Construction activity noise is characterized by the combined duty cycle and resulting noise emission of each piece of equipment. The duty cycle is expressed in terms of the "usage factor" of the equipment, which is the percentage of time during the work period that the equipment is operating under load or at near full power. In addition to the minute-by-minute variations in noise producing activities, construction projects are carried out in several different phases.

Standardized federal or state criteria have not been adopted for assessing construction noise impacts. Therefore, municipal planning criteria are generally developed and applied on a project-specific basis. Construction project noise criteria take into account the existing noise environment, the time-varying noise during the various phases of construction activities, the duration of the construction, and the adjacent land use.

During daytime hours, construction work should comply with Russian construction noise threshold criteria (55 dBA for residential area). Normally, no evening or nighttime construction activity is permitted in areas having noise-sensitive receptors.

1. NOISE LEVELS OF CONSTRUCTION EQUIPMENT

For most construction activities, different construction equipment operate in one of two modes, stationary and mobile. Stationary equipment are those that operate in one small area for one or more days at a time, with either a steady power cycle operation (e.g., pumps, generators, compressors, etc.) or a periodic impulsive operation (e.g., pile drivers, pavement breakers, etc.). Mobile equipment are those that frequently move around a much larger area of the construction site with power applied in a rapidly changing, non-steady fashion (e.g., bulldozers, loaders, etc.), or move to and from the construction site (e.g., haul trucks, material trucks, etc.). These variations in operating power and location add a great deal of complexity in characterizing the source noise level of a given piece of construction equipment. This complexity can be simplified by determining the equipment noise level at a reference distance from the equipment operating at full power and adjusting its full power noise level according to the duty cycle or “usage factor” of the particular construction activity and project phase to determine the characteristic noise level of the operation during each phase.

To evaluate the noise levels of construction vehicles special measurements complying with Russian standards were held. The measurements showed that the sound levels of construction equipment vary from 63 to 99 dBA at the reference distance of 7.5 meters. The analysis of results of measurements showed that only 2 percents of vehicles have noise levels lower than 70 dBA, 14 % – 70-75 dBA, 38 % – 75-80 dBA, 24 % – 85-90 dBA and 6 % – more than 90 dBA. The less noisy vehicles are those produced by foreign producers “Caterpillar” and “Komatsu”.

The researches were held to determine the noise levels at different stages of construction works for the road construction. The amount of used vehicles and measured noise levels are shown in table 1.

Table 1. Variation of noise levels of construction site dependently on the phase of construction

No.	**Construction phase**	**Amount of vehicles used**	**L_{eq}, dBA, measured at the given distance from the construction site, m**	
			15	**30**
1	Asphalt laying	5	76	72
2	Loading	4	67	63
3	Asphalt cutting	4	80	75
4	Land planning and preparation	5	70	66
5	Settling of bearers	4	90	85
6	Land works	7	73	69

The researches show that the construction works despite of their short-term impact are the most annoying ones since the noise levels generated are very high. The conflicts with the standard values make 15-35 dBA at the short distance. So, the levels of construction works should be reduced using different noise protection measures. One of the possibilities is to use the elements of landscape (such as cutting or berm) as it is shown below. From the other hand, the close proximity of the construction site to the nearby building can influence noise levels in an opposite way increasing the resulting sound level.

2. NOISE INCREASE WITH REFLECTION FROM NEARBY BUILDING

The man made constructions nearby the construction site influence the noise propagation. The construction noise attenuations at the presence of reflecting building.

On figure 1 the construction noise spectrum is given for the case when the construction works are allocated nearby a big long building. The building is the secondary reflector of sound. So, at some frequencies the sound attenuation makes only 2-3 dB. The reflection effect increases with the decrease of the distance from the construction site to the building.

On fig. 2 the measured values of sound attenuation are given. At the triple attenuation (from 7.5 m to 60 m) the sound attenuation makes only 10 dBA instead of 12 dBA that takes place in a free field.

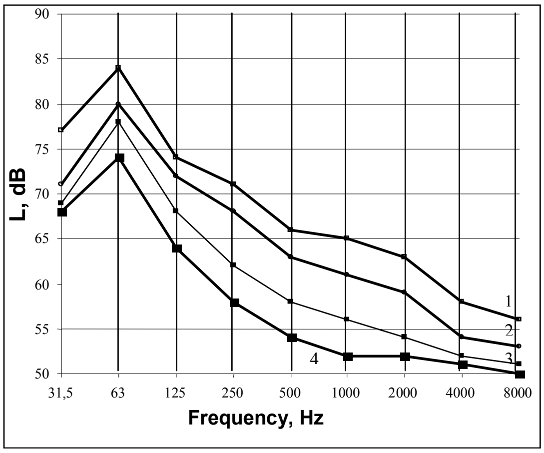

Fig. 1. Noise spectrum at loading works (excavator Hitachi EX 300, wheeled excavator Hitachi, Stalowa Volat 34B and "Tatra" lorry) at work nearby a big building at the distances: 1 – 7.5 m; 2 – 15 m; 3 – 30 m; 4 – 60 m

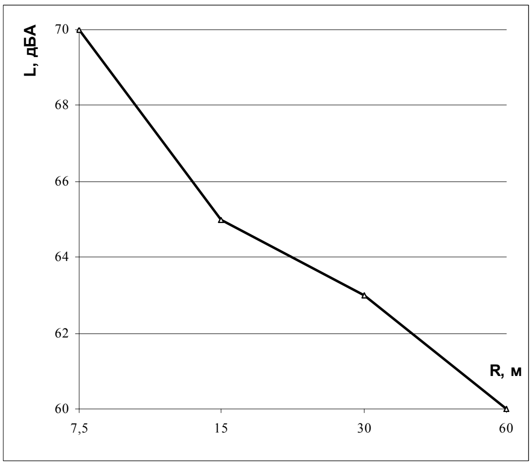

Fig. 2. Noise attenuation at loading works (excavator Hitachi EX 300, wheeled excavator Hitachi, Stalowa Volat 34B and "Tatra" lorry) at work nearby a big building

Finally, the value of addition for the reflection of sound was obtained by experimental way. The addition for the reflection with a big long building makes +2 dBA.

3. NOISE REDUCTION WITH CUTTINGS

Besides, the construction noise attenuation was studied at the presence of cutting and berm. On fig. 4 the noise spectrum are given for the reference points shown on fig. 3. The distance from the construction site makes 30 m, the height of cutting is 2-3 m. The researches show that the cutting gives an attenuation of 2-4 dB.

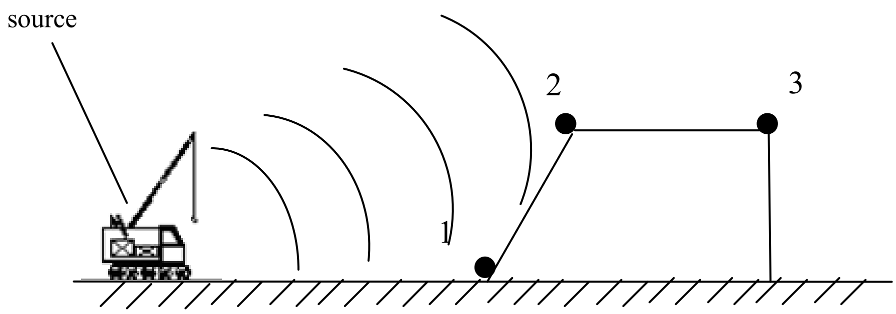

Fig. 3. Scheme of measurements with the cutting: 1-3 – reference points

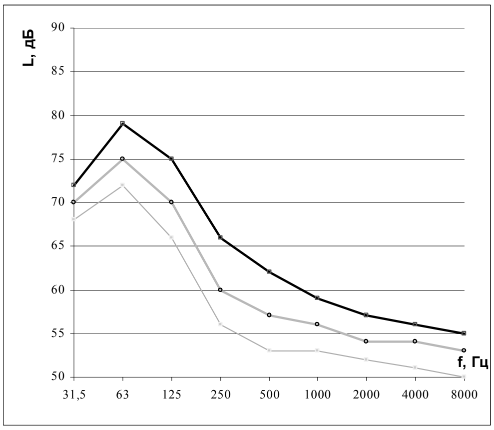

Fig. 4. Noise attenuation at land works depending on the distance with and without cutting: 1 – at the distance of 30 m from the construction site (65 dBA); 2 – at the distance of 60 m in a free field (62 dBA); 3 – at the distance of 60 m with cutting (58 dBA).

The noise reduction with the cutting was studied dependent on the distance from the source and height of the cutting. The results of measurements are given in table 2 and on fig. 5. The analysis of obtained data shows that at the increase of the height of cutting two times the noise attenuation increases on 5-6 dBA. At the increase of the distance from the noise source to the edge of cutting the noise attenuation decreases.

Table 2. Influence of the distance from the source to the cutting on noise attenuation

Height of cutting, m	**Noise attenuation, dBA, at the distance from noise source to the edge of cutting, m**		
	7	**10**	**30**
3-4	16	8	4
9.5	22	15	8

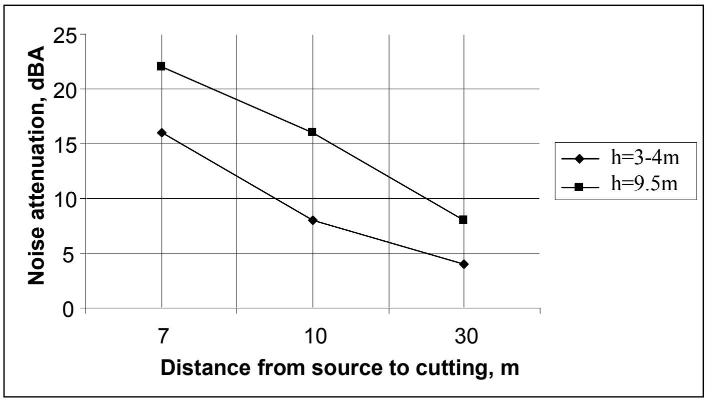

Fig. 5. Noise attenuation with the cuttings of different height

4. NOISE REDUCTION WITH BERMS

On fig. 7 the noise attenuation with the berm of the height of 6-8 m is shown for the reference point 1-3 (fig. 6). The noise attenuation with the height of the berm (reference point 2) makes 2-4 dB and noise attenuation with the width of the berm makes 6-9 dB.

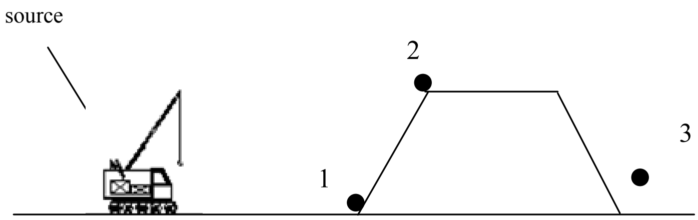

Fig. 6. Sound propagation over the berm: 1-3 – reference points

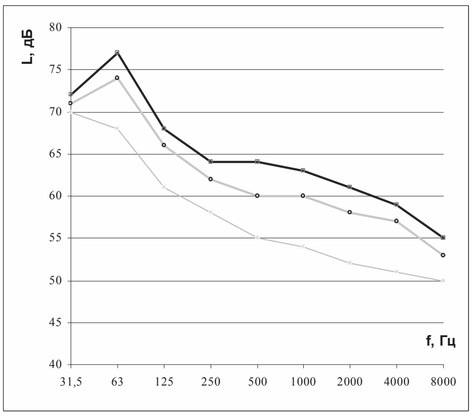

Fig. 7. Influence of berm on construction noise attenuation: 1 – reference point at the lower edge of the berm (70 dBA); 2 – reference point on the upper edge of the berm (67 dBA); 3 – reference point behind the berm at the distance of 25 m (58 dBA)

5. ADDITIONS FOR THE CALCULATION OF CONSTRUCTION NOISE PROPAGATION

The measured additions for the noise attenuation with different elements of landscape of the same height are given in table 3 and on fig. 8.

In result of investigations it was obtained that the cutting is more efficient tool to reduce construction noise. With the similar conditions the noise attenuation with the cutting is on 2-3 dBA bigger than for the berm. The biggest difference of noise attenuations is at the smaller distances: 6-7 dBA at the distance of 25-50 m. So, the noisiest works are better to conduct in the cutting.

Table 3. Noise attenuation with the cutting and embankment

Type of landscape	Noise attenuation, dBA, at the distance from the source, m								
	25	50	80	100	150	200	250	300	350
Cutting	15	12	7,5	7	6,5	6	5.5	5	5
Berm	8	6	5	3.5	3.2	2.8	2.3	1.7	1.4

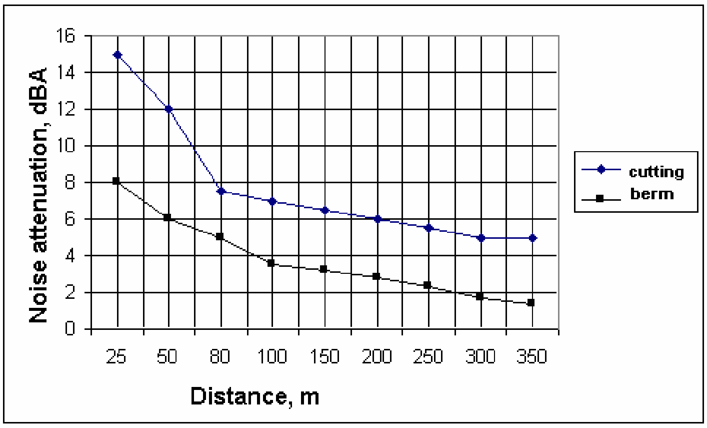

Fig. 8. Noise attenuation with the cutting and berm

The summary of the results are given in table 4. The obtained additions should be applied at the calculation of construction noise propagation.

Table 4. Additions for the construction noise propagation at different landscapes

Landscape	Addition, dBA
Building nearby construction site	+2
Berm of the height of 2-3 m	More than -3
Berm of the height of 6-8 m	More than -8
Cutting	More than -10

CONCLUSIONS

The construction works are very annoying to the public due to their high levels and close proximity to the residential areas especially in case of building or reconstruction of roads. At the design stage of the road the noise protection measured for the period of construction should be planned. For this purpose the calculation of the impact of construction noise to the noise-sensitive receptors should be carried out. The calculations should take into account the influence of the elements of landscape to the noise attenuation. Thus, the sound increase with the reflection at the building could add up to 2 dBA in the result sound level. The cutting and the berm could reduce noise levels on 6-10 dBA.

REFERENCES

[1] "Construction noise threshold criteria and control measures", Advanced Engineering Acoustics, p. 1-40 (2002)
[2] M.V. Butorina, N.I. Ivanov, N.N. Minina, *Evaluation of acoustical impact at the design of linear transport objects,* Proceedings of Annual Meeting of NIPI TRTI (Saint-Petersburg, 2006)