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Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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SPECTRAL ADAPTATION TERMS DETERMINATION FOR BUILDING AIRBORNE SOUND INSULATION REQUIREMENTS AGAINST RAILWAY NOISE

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Abstract

Railway transport increases the noise levels in the environment 24 hours a day. As a rule, this leads to disruption of citizens' dormancy during the daytime and especially at night. The most widely used means of reducing railway noise are sound road barriers and soundproof structures of buildings located in the first echelon and facing the railway tracks. The airborne sound insulation of such protective systems is of primary importance. According to the International Standard ISO 717-1:2013 requirements and performance of airborne sound insulation of buildings are given with the help of single-number parameters and evaluated as the sum of a weighted apparent sound reduction index and the corresponding member of the spectral adaptation. The International Standard was partially introduced in Russia as the National Standard GOST R 56769-2015. In the paper the comparison is made of the A-weighted normalized noise spectra for various categories of the railway transport operated on Russian railways with the noise spectra used in the International and Russian Standards to calculate the members of the spectral adaptation. By the specific example the divergences in obtained values of spectral adaptation terms are shown and corresponding recommendations are offered.

Keywords: railway transport, noise, sound insulation, spectral adaptation term

1 Introduction

Numerous studies have shown that the noise levels from railway transport in buildings and in the residential area significantly exceed the sanitary standards in many cases (by tens decibels). So, according to the data of the GBPU "Mosecomonitoring", the excess for Moscow is 10-20 dB. As a result, the reduction of noise from railway transport is of great importance for cities and settlements through which rail lines pass and which use local railway lines and open metro stations. The most common measures to reduce railway noise are the installation of noise barriers and increasing the sound insulation of exterior structures of buildings located near railway lines, the translucent parts of which are facing the railway tracks [1, 2]. In this connection, the isolation of air noise by such external constructions of buildings is of paramount importance. In accordance with the International Standard ISO 717-1: 2013 [3], the requirements and characteristics of airborne sound insulation of buildings and building elements are established using single-number parameters and evaluated as the sum of the weighted apparent noise reduction index R'_{w}, $R'_{45°,w}$, $R'_{tr,s,w}$ and the corresponding member of the spectral adaptation (spectral adaptation term) C, C_{tr}. The International Standard was partially introduced in Russia in 2016 as the National Standard GOST R 56769-2015 [4]. Evaluation of sound insulation of airborne noise with the help of single-number parameters makes it possible to simplify the formulation of acoustic requirements in building documents. It is

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used in advertising brochures of manufacturers of soundproofing products and is determined during testing of enclosing structures [2, 5-7]. According to their values, the ability of enclosing structures to provide acoustic comfort in building premises through sound insulation from internal and external sound sources is assessed [8, 9]. As a result, the current Rules of Codes in Russia SP 51.13330.2011 [10] and SP 275.1325800.2016 [11] the required limit values for airborne sound insulation indexes for the residential, public buildings and auxiliary buildings of manufacturing enterprises are established, as well as sound insulation of windows depending on the values of equivalent sound pressure levels at the facade of residential and administrative buildings with the most intensive traffic. The sum of the weighted noise reduction index and the spectral adaptation term corresponds to the reduction of the A-weighted sound pressure level ΔL_A of the sound incident on the enclosing structure. This is the sound insulation parameter R_{Atran} for external translucent enclosure, which characterizes the isolation of outdoor noise created by the urban traffic streams [10, 11], that is, this sum gives a widely used in practice one-number estimate of the soundproofing ability of an enclosure. It was shown in [12, 13] that the discrepancies in such an estimation of the sound-insulating ability of the enclosing structures and noise barriers can be significant (4-8 dB), depending on the spectrum of the noise incident on the obstacle, that is, the actual soundproofing capacity of the obstacle essentially depends on the spectrum of penetrating sound. At the same time, in ISO 717-1: 2013 [3], only two types of spectra are used to determine the spectral adaptation term, which is intended to take into account the nature of the penetrating noise spectrum: the spectrum of pink noise, and the traffic noise spectrum corresponding to the A-weighted normalized noise spectrum of urban vehicles in accordance with the European Standard EN 1793-3: 1997 [14]. In this paper, a comparison of the A-weighted noise spectra for different categories of railway transport operated on Russian railways is carried out with the noise spectra used in the International [3] and Russian [4] Standards for calculating the spectral adaptation terms. Since the railway noise is given only by octave spectra, spectra in octave frequency bands set by Standards are considered also. By the specific example the divergences in obtained values of spectral adaptation terms are shown and corresponding recommendations for the application of Standard spectra for rating of sound insulation of enclosing structures of buildings in relation to railway noise are offered.

2 Spectra for spectral adaptation term determining

As noted in Annex A of International Standard ISO 717-1:2013, the spectral adaptation terms C and C_{tr} were introduced into ISO 717-1:1996 to take into account different spectra of noise sources (such as pink noise and road traffic noise) and to assess sound insulation curves with very low values in a single frequency band (the validity of the rating obtained with the reference curve alone is limited for such cases). C and C_{tr} have not been included as one single-number quantity, but have been included as separate numbers.
There are two spectra applied in ISO 717-1:2013 as the generalized spectra: spectrum No. 1 corresponding to pink noise, and spectrum No. 2 corresponding to noise of road transport. The A-weighted sound pressure levels for the specified spectra at octave bands of the enlarged frequency range are resulted in Table 1.

Table 1 Sound level spectra to calculate the adaptation terms

Spectrum type	Sound level L_{Aij} [dB] at octave band with central frequency [Hz]						
	63	125	250	500	1000	2000	4000
Spectrum No. 1 to calculate C	-32	-22	-15	-9	-6	-5	-5
Spectrum No. 2 to calculate C_{tr}	-18	-14	-10	-7	-4	-6	-11

Note: All levels are A weighted and the overall spectrum level is normalized to 0 dB with precision -0.4 (spectrum No. 1) +0.3 (spectrum No. 2).

With respect to railway noise, spectrum No. 1 is recommended to apply at rating of sound insulation railway traffic at medium and high speeds, spectrum No. 2 at rating of sound insulation of railway traffic at low speeds. The spectrum adaptation terms C_j shall be calculated with the sound spectra given in Table 1 from the following equation:

$$C_j = -10\lg\sum_{i=1}^{n} 10^{\frac{L_{Aij}-X_i}{10}} - X_w \tag{1}$$

where j is the subscript for the sound spectra Nos. 1 and 2; L_{Aij} are the levels as given in Table 1 at the frequency i for the spectrum j; X_i is the apparent sound reduction index R_i' at the measuring frequency i, given to one decimal place; the subscript i corresponds to the serial number for the octave bands 63 Hz to 4000 Hz (n = 7).
Spectrum No. 1 corresponds to the A-weighted spectrum of a pink noise for which the sound pressure levels in frequency bands are constant and can be represented by the expression $L_f = L_0 + C$ [13], where L_0 corresponds to the product of the square of the sound pressure produced by the source of the pink noise at some reference frequency f_0, by this frequency ($L_0 = 10\lg\,[p_0^2 \cdot f_0 / (4 \cdot 10^{-10})]$); C = -1.6 dB. In order to obtain the values of the spectrum given in Table 1, with an accuracy of 0.1 dB should be taken L_0 = -3.5 dB. As a result the total A-weighted sound pressure level of the spectrum No. 1 appears normalized to 0 dB (L_A = 0 dB), that allows to use the sum $C_1 + X_w$ for rating of the total A-weighted sound pressure level decrease of sound falling on a protecting design.
The spectrum No. 2 can be received from the reference transport noise spectrum given in Table 2, by subtracting from it the value of A-weighted sound pressure level corresponding to this spectrum which is equal 75 dB. Thus, the sum $R_w + C_{tr}$ is equal R_{Atran} and characterizes the isolation of external noise created by urban transport streams [13]. As a result this sum can be used to estimate the reduction of the total A-weighted sound pressure level by a protecting design.

Table 2 A-weighted sound pressure levels of the reference transport noise spectrum

f [Hz]	63	125	250	500	1000	2000	4000
L_{Aoct} [dB]	50	61	65	68	71	69	63

3 A-weighted normalized spectra of railway noise

The relative spectra emitted by railway transport operated on Russian railways are entered in the Interstate Standard GOST 33325-2015 [15] and given in Table 3. The corresponding A-weighted normalized spectra of the railway transport shown in the same table are obtained by subtracting from the relative spectra of the frequency weighting A of sound level meter in accordance with the International Standard IEC 61672-1:2002 [16]. The overall A-weighted spectrum level is normalized to 0 dB with precision -0.2 +0.1 dB.
It is specified in appendix A of International Standard ISO 717-1:2013 that if the A-weighted spectrum of a certain kind noise is known, it can be compared to the spectra given in Table 1 and to choose a corresponding member of spectral adaptation. Comparison with the data in Table 1 is performed in Figure 1. The A-weighted normalized spectra for trains of all categories are closer to the spectrum No. 1 in the low and mid-frequency domain (octave bands with centre frequencies 63 – 250 Hz, for passenger and high-speeds trains octave bands with centre frequencies 500 and 2000 Hz too) and to the spectrum No. 2 in the octave bands with centre frequencies 1000 and 4000 Hz. For any category of trains the spectrum does not approach any one of the spectra recommended in ISO 717-1:2013 over the entire frequency range. Only for the goods trains the spectrum is closer to the spectrum No 2 in five of the seven octave

bands. In this connection the calculations have been executed of spectral adaptation terms of special translucent glazing consisting of a three-layer safety glass with a thickness of 16-16-8. The values of the apparent sound reduction index $R'_{45°}$ at octave frequency bands measured in accordance with ISO 140-5 [17] are given in Table 4. Values C = -1 dB and C_{tr} = -6 dB were received at use of spectra Nos. 1 and 2. When using the A-weighted normalized spectra for trains from Table 3 the calculated value of spectrum adaptation terms is equal to -1 dB for all train categories except good trains for which $C_{g.t}$ = -3 dB, that is also closer to the value of C.

Table 3 Spectra of railway noise

Noise source	Sound pressure level [dB] at octave band with central frequency [Hz]						
	63	125	250	500	1000	2000	4000
Relative spectra							
Passenger train with locomotive traction	-12.6	-15.5	-18.4	-5.6	-3.7	-6.4	-11.5
Goods train (all tipes)	2.8	-5.8	-6.0	-2.5	-5.2	-7.0	-12.1
Local train	-15.1	-17.0	-17.3	-4.3	-3.3	-6.2	-13.5
High-speed train	1.0	-4.5	-13.9	-7.2	-4.6	-5.1	-10.8
A-weighted normalized spectra L_{Ai}							
Passenger train with locomotive traction	-38.8	-31.6	-27.0	-8.8	-3.7	-5.2	-10.5
Goods train (all tipes)	-23.4	-21.9	-14.6	-5.7	-5.2	-5.8	-11.1
Local train	-41.3	-33.1	-25.9	-7.5	-3.3	-5.0	-12.5
High-speed train	-25.2	-20.6	-22.5	-10.4	-4.6	-3.9	-9.8

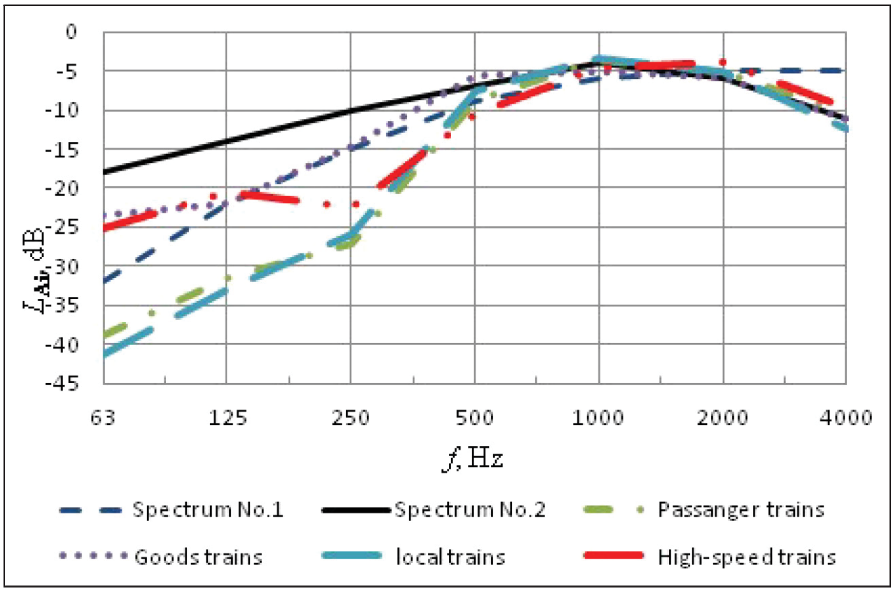

Figure 1 Sound level spectra to calculate the adaptation terms

Table 4 Sound reduction index of special translucent glazing

f [Hz]	63	125	250	500	1000	2000	4000
$R'_{45°}$ [dB]	26.3	32.1	37.4	42.4	42.9	47.3	54.2

4 Conclusions

The performed analysis shows that for all categories of trains operated on the railways of the Russian Federation the most appropriate spectrum for calculating the spectral adaptation term according to the ISO 717-1:2013 method is spectrum number 1. Further studies can be aimed at obtaining a sufficient amount of calculated and experimental data on the determination of the sound insulation parameters of various enclosing external constructions of buildings from railway noise with using the A-weighted normalized spectra of various categories of trains given in this paper.

References

[1] Kotzen, B., English, C.: Environmental noise barriers. A guide to their acoustic and visual design. Second edition, Tailor & Francis, London, New York, 2009.

[2] Shubin, I.L., Tsukernikov, I.E., Nikolov, N., Pisarsky, A.: Bases of designing transport noise barriers, Manual for students of high schools, PH “BASTET”, Moscow, 2015.

[3] ISO 717-1:2013, Acoustics — Rating of sound insulation in buildings and of building elements— Part 1: Airborne sound insulation, ISO, Geneva, Switzerland, 2013.

[4] GOST R 56769-2015 (ISO 717-1: 2013) Buildings and structures. Rating of airborne sound insulation, Standartinform, Moscow, 2015.

[5] Materials for sound insulation of buildings and constructions, SC “Acoustic Traffic”, Kiev, 2014.

[6] Tsukernikov, I.E., Shubin, I.L.: Declaration and verification of airborne sound insulation values for sound insulators in use in Russia, Zhilishchnoe Stroitel’stvo, 10, pp. 37-39, 2011.

[7] Osipov, G.L., Bobilev, V.N., Borisov, L.A. et al.: Sound insulation and absorption, Manual for students of high schools, SC “Publishing house AST”,SC “Publishing house Astrel”, Moscow, 2004.

[8] Boganik, A.G.: Acoustic comfort. Part I. Sound- and vibro insulation from internal sources in a residential building, Building technology, 4(59), pp. 1-7, 2008.

[9] Boganik, A.G.: Acoustic comfort. Part II. Sound- and vibro insulation of a residential building from external sources of sound and vibration, Building technology, 7(62), pp. 1-5, 2008.

[10] SP 51.13330.2011, Sound protection, Minregion of Russia, Moscow, 2010.

[11] SP 275.1325800.2016, Design of sound insulation of protecting designs of residential and public buildings, SC “Technorma”, Moscow, 2017.

[12] Tsukernikov, I.E., Nevenchannaya, T.O., Nekrasov, I.A.: A-weighted sound pressure level calculation for penetrating noise, 37th International Congress Inter-Noise 2008, Paper in 08 860, Shanghai, China, 26-29 October 2008..

[13] Tsukernikov, I.E., Shubin, I.L., Nevenchannaya, T.O.: Assessment of sound level decrease by noise barrier, Zhilishchnoe Stroitel’stvo, 6, pp. 40-44, 2012.

[14] EN 1793-3:1997, Road traffic noise reducing devices – Test method for determining the acoustic performance – Part 3 Normalized traffic noise spectrum, CEN, Brussels,1997.

[15] GOST 33325-2015, Noise. Calculation methods for external noise emitted by railway transport, Standartinform, Moscow, 2016.

[16] IEC 61672-1:2002, Sound level meters. Part 1. Technical requirements, IEC, , Geneva, Switzerland, 2002.

[17] ISO 140-5:1998, Acoustics — Measurement of sound insulation in buildings and of building elements —Part 5: Field measurements of airborne sound insulation of façade elements and façades. ISO, Geneva, Switzerland, 1998.