inter•noise 25th Anniversary Congress – Liverpool 96

INCE: 31.1

BARRIERS FOR RAILWAY NOISE: MEASUREMENTS AND CALCULATIONS OF THE INSERTION LOSS

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1. INTRODUCTION

Measurements of the insertion loss of a barrier were carried out at three distances that are 25 m, 50 m and 100 m to a railway line with microphones placed at different heights. The measurements were made along a small street in an area populated with small single-family houses. To define the noise source the railway noise was measured without any noise barrier at a distance of 25 m from the railway line. The measurements of the railway noise have the advantage of a well defined noise source at a certain distance to the noise barrier. With this it is possible to investigate common approximations for calculating the noise reduction by barriers. The measurement results were compared with calculations of noise reduction of the A-weighted and frequency dependent sound pressure level. Different positions of the noise source were calculated and compared with the measurements of the insertion loss of the barrier.

2. MEASUREMENTS AND CALCULATIONS

Measurements of the railway noise

The noise reduction by the barrier was measured at a distance of 25 m (height 3,5 m, 7 m and 11 m above the track), 50 m (height 3,5 m) and 100 m (height 3,5 m and 7 m) from the center of the two tracks. The center of the noise wall (thickness 0,3 m) was at a distance of 3,65 m from the axes of the nearest track and had a height of 3,5 m above the track. The tracks were on a bed of broken stones. The railway line is a straight line and the measurement positions were perpendicular to the railway line and also it is perpendicular to the noise barrier. The surface of the barrier facing the track was absorbent. To define the noise source the railway noise was measured without any noise wall at a distance of 25 m (from the center of the two tracks) at the heights of 3,5 m and 7 m above the track. Between the measurement position with and without noise barriers there was a distance of 500 m approximately. The rails were on an embankment with a height of (approximately) 2 m above the surrounding. The equivalent sound pressure level was evaluated at all measurement positions.

Unfortunately, the traffic on the two tracks was not symetrical. There were 9 freight cars on the track nearer to the noise barrier and only one train was on the other track. Therefore only the measurements of the trains on the nearer track were taken into account. Measurements of 6 trains consisting of freight cars and 3 trains with special freight cars for the transport of lorries (Niederflurwagen) were made.

The measurements were made in the evening hours. The meteorological parameters were also recorded: The temperature was measured at heights of 3 m, 8 m and 13 m above ground. During the noise measurement the temperature at a height of 3 m was in the range of -5,3 to -6,0 °C, at 8 m -3,5 to -4,2 °C and at 13 m -3,1 to -3,7 °C. These temperature distribution characterizes a stable meteorological situation with a typical evening inversion. The relative humidity was in the range of 96 % and there was no wind.

Calculation of railway noise propagation

The railway noise propagation is calculated in Austria according ÖAL Guideline 30 [1, 1990]. In this guideline it is assumed that the noise source is at a height of 0,3 m above the axis of the track. In the first edition of the guideline (from the year 1990), the railway noise is assumed to have dipole radiation characteristics. This has been changed to a combination of a dipole with a small portion of a spherical radiation characteristics in the second edition from the year 1995 [1, 1995]. This change of the radiation characteristics is usefull and necessary for measurement points near to the track at a great height.

In that case which was measured and calculated the source line was portioned into sections with a length of 10 m represented by source points located at a height of 0,3 m above the axis of the track. With this source point locations and with help of guideline [1] the energy equivalent noise level was calculated in octave band steps. This calculation was done to

find the noise reduction for the different measurement locations at 25 m, 50 m and 100 m distance from the track with the mentioned heights.
The **insertion loss of the barrier** was calculated with help of the experimental results of Maekawa [2] with an engineering approximation, e.g. [3]. The noise reduction is dependent on the frequency (calculated in octave band steps in the range from 63 to 8000 Hz) and the path difference from source point to receiver point with and without screen. The receiver level at a certain point is dependent on the distance to the source point and the sound reduction of the screen. These frequency dependent sound levels are calculated for each source and receiver point combination. The calculation scheme with the corresponding equations will be found in [3]. For an assumed line source like a railway line there are a large number of source points and also path differences from all source points to the assumed receiver points. Any of these path differences leads to the corresponding sound reduction of the noise barrier. Finally the calculation leads to an averaged sound reduction of the noise barrier of the whole pass-by.

3. A-WEIGHTED NOISE REDUCTION CAUSED BY THE SCREEN

The measurement position without the screen (distance 25 m, height 3,5 m above the track) was used to define the noise source. The measurement results behind the noise wall were compared with the sound levels without the screen with respect to the geometrical divergence calculated with the above mentioned propagation model. The calculation doesn´t include the ground effects.
The measurements include the common uncertainity of measuring railway noise of freight cars (different real source heights of the freight cars in comparison with passenger trains) and the changing meteorological situation during the measurement time. The following table includes the measured A-weighted equivalent sound pressure levels as well as the A-weighted sound level difference between the measurement and the calculation [1, 3] of the sound level. The mentioned sound level difference seems to be like a quality factor between measurement and calculation. The insertion loss of the noise barrier is calculated by using the results of Maekawa [2]. The positon of the noise source was assumed at the axis of the track at a height of 0,3 m (according the Austrian Guideline [1]).

Train type (freight cars), number of railway carriages	time	A-weight. sound level (dB) Sound level difference (measurement - calculation) dB						
sound propagation		free	with noise wall					
measurement dist. (m)		25	25	25	25	50	100	100
measurement height (m)		3,5	3,5	7,0	11,0	3,5	3,5	7,0
freight car with lorries, 17	20:07	82,0	62,9	65,9	69,9	59,8	55,0	56,3
			1,1	-0,2	-2,0	0,4	1,2	0,3
freight car, 16	20:19	82,2	62,9	65,7	69,3	59,2	55,7	56,8
			1,3	0,2	-1,2	1,2	0,7	0
freight car with lorries, 20	21:06	81,9	65,3	68,4	71,2	61,0	57,5	56,6
			-1,4	-2,8	-3,4	-0,9	-1,4	-0,1
freight car with lorries, 20	21:23	79,8	62,4	65,2	67,2	57,3	54,3	52,9
			-0,6	-1,7	-1,5	0,7	-0,3	1,5
freight car, 29	21:35	84,1	65,0	68,1	70,8	59,9	57,8	56,5
			1,1	-0,3	-0,8	2,4	0,5	2,2
freight car, 38	22:15	84,9	68,2	71,1	73,2	63,0	59,8	58,7
			-1,3	-2,5	-2,4	0,1	-0,7	0,8
freight car, 30	22:19	83,5	66,9	69,8	72,3	62,1	57,9	56,8
			-1,4	-2,6	-0,4	-0,2	-0,2	1,3
freight car, 30	22:28	83,8	68,3	71,2	73,5	63,5	58,8	58,1
			-2,5	-3,7	-3,8	-1,5	-0,8	0,3
freight car, 30	22:33	82,8	67,1	70,1	73,5	62,8	57,8	56,5
			-2,3	-3,6	-4,8	-1,8	-0,8	0,9

In railway noise calculation models a lot of **source point locations** are used. In the following, the influence of various source point locations is calculated. In Germany until 1990 a source point location at the head of the nearest rail was used and thereafter the source point is located at the axis of the track. The height above the track was in both cases 0 m [4].
With regard to this the above mentioned calculations were made to compare the various source point locations. To compare the results a difference between measured and calculated A-weighted sound levels of all trains were evaluated. The deviation of the sound level difference

between measurement and calculation of the various source point locations is represented in the following table.

source point location	Deviation (measurement - calculation) of the A-weighted sound level (dB)
Axis of the track, height 0,3 m	-0,7
Axis of the track, height 0,0 m	-1,5
Nearest track, height 0,0 m	-2,3

The comparision of the results shows that a source point location at the axis of the track with a height of 0,3 m seems to be best suited. These results have the limitation that only 9 freight trains were analysed and no passenger trains were included. The measurements include the curved acoustic rays due to the meteorological synoptic condition. The calculations are based on the geometrical divergence from the distance 25 m to 100 m using the Austrian propagation model.

4. FREQUENCY DEPENDENT INSERTION LOSS CAUSED BY THE BARRIER

In the following the frequency dependent insertion loss caused by the barrier is compared with the experimental results of Maekawa [4]. Maekawa represents the sound attenuation depending on the Fresnel Number ($N = 2\ z / \lambda$), which also includes the wavelength (λ) of the sound and the path difference (z) with and without screen.

The frequency dependent and the A-weighted sound level is calculated for each source - receiver point combination. Each source - receiver point combination leads finally to an A-weighted sound reduction caused by the noise barrier. The complete pass-by of the train leads to a "general" A-weighted noise reduction. This "general" A-weighted noise reduction is compared with the noise reduction of the single source points. With this it is possible to find a "corresponding source point" along the track which has the same A-weigthed noise reduction as the whole noise barrier. With this source point it is possible to find a "corresponding path difference", which is used for the further calculation. This "corresponding path difference" with and without noise wall is used to calculate the Fresnel number with respect to the frequency and the "corresponding Maekawa noise reduction" which is represented in the diagram.

In the following diagram "the corresponding path difference z" is used for the calculation of the Fresnel Number N and it is compared with the measured sound attenuation.

The sound attenuation in the range of Fresnel Number N = 1 seem to be a result of the ground effects and in the range of N = 50 it is a result of the absorption in the air.

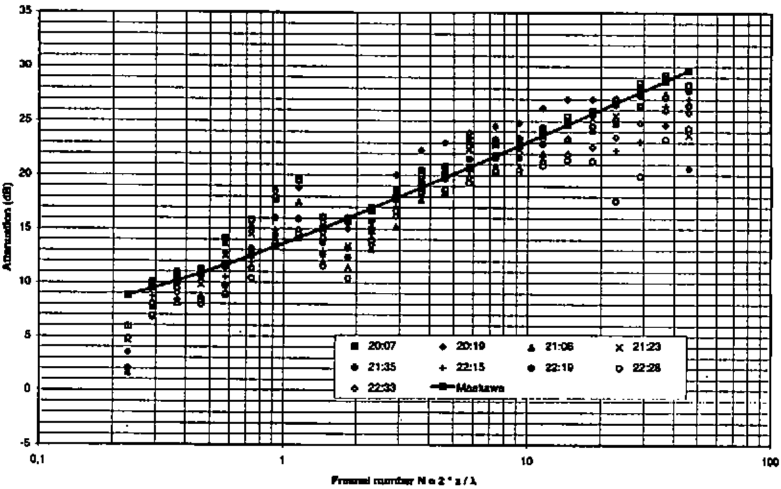

Figure 1: Sound attenuation of railway noise through a barrier dependent on the Fresnel Number N which includes the path difference z with and without screen and the wavelength λ (measurement position at a distance of 25 m and at a height of 3,5 m)

References

[1] Berechnung der Schallimmission durch Schienenverkehr (Calculation of the noise caused by railways), Österreichischer Arbeitsring für Lärmbekämpfung ÖAL (Austrian Noise Abatement Society) Guideline No. 30, Vienna 1990, 1995

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[4] Akustik 03, Richtlinie zur Berechnung der Schallimmissionen von Schienenwegen, (Guideline to calculate the noise of railway lines), Deutsche Bundesbahn, Bundesbahn - Zentralamt München 1976, 1990