Required Attenuation of Aircraft Noise in Buildings in the Light of Data from the Chopin Airport Monitoring

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Abstract

The minimum attenuations of aircraft noise required by the Polish Standards concerning acoustic insulation and noise levels inside buildings have been compared. Data from the noise monitoring system of the Chopin Airport were used.

The minimum attenuation required by PN-B-02151-02:1987 differs from that required by PN-B-02151-3:2015-10. The highest required attenuation occurs when taking into account the maximum sound level L_{Amax} of aircraft noise. The requirements related to L_{Amax} are 2.0 to 7.8 dB higher than those associated with the equivalent sound level L_{Aeq}.

If the number of flight operations at night reaches the allowed maximum number of forty, the requirements related to L_{Aeq} may be decisive.

The requirements connected with L_{Aeq} according to PN-B-02151-02:1987 are 0.6 to 2.6 dB higher than coming from PN-B-02151-3:2015-10.

Keywords: building acoustic, aircraft noise, permissible noise level in buildings

1. Introduction

Aircraft noise is the third most dominant source of environmental noise in Europe in terms of the number of people exposed [1]. However, due to the adverse impact on people, the WHO recommends lowering aviation noise indexes to values lower than the recommended ones for road and rail noise [2].

The ICAO in a balanced approach to noise management [3] has identified instruments to mitigate noise impact, such as building codes and building noise insulation programs, as one of the principal noise reduction measures. The practical implementation of these instruments results from the conditions in individual countries [4]. However, it has generally been known for a long time that in the bedrooms the equivalent sound level of L_{Aeq} within 8 hours of the night should not exceed 30 dB and 45 dB L_{Amax} for a single acoustic event [5].

There are two standards in Poland regarding the protection against aircraft noise in buildings. PN-B-02151-3:2015-10 let calculate the sound reduction indexes required in buildings under the construction process [6], while PN-B-02151-02:1987 gives the permissible noise levels in residential rooms [7]. This study compares the requirements of noise protection in buildings resulting from the above-mentioned standards. The aircraft noise data were taken of the noise monitoring system of the Chopin Airport in Warsaw [8].

2. Required attenuation of a building envelope

The difference D_A of A-weighted sound level outside the building $L_{A,\mathrm{out}}$ and inside the building $L_{A,\mathrm{in}}$ is a measure of noise attenuation by the building envelope.

$$L_{A,out} - L_{A,in} = D_A \tag{1}$$

In order to the requirements for protection against aircraft noise to be met, D_A has be at least equal to the minimum value resulting from the standards:

$$D_A \geq D_{A,min} \tag{2}$$

$D_{A,min}$ is the required attenuation of aircraft noise through the partitions of given room. The value of $D_{A,min}$ equals to the difference of the level of external noise and the permissible noise level in the room. As a rule, higher noise protection requirements apply to the nighttime.

3. Aircraft noise levels

The data from the Chopin Airport noise monitors were used including the A-weighted sound exposure level L_{AE}, A-weighted maximum sound level L_{Amax}, date and time of the event, type of aircraft and type of flight operation

With regard to the airports where L_{Amax} is not measured, this noise index can be estimated using the methods described in the literature [6, 9].

Figure 1 shows locations of noise monitors of Chopin Airport. Only monitoring points located on inbound and outbound tracks were included.

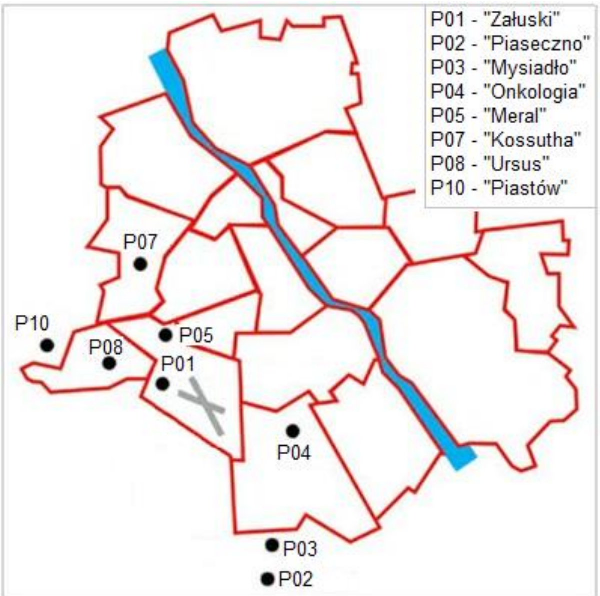

Figure 1. Layout of the Warsaw Chopin Airport noise monitors (based on [8])

The average value of the sound exposure level L_{AE} at monitors was calculated from the equation

$$L_{AE} = 10\log\left(\frac{1}{n}\sum_{i=1}^{n} 10^{0,1L_{AE,i}}\right) \tag{3}$$

where $L_{AE,i}$ is A weighted sound exposure level of the *i*-th flight operation, and *n* is the number of flight operations during the whole year or in the three consecutive months with the highest number of flights at night.

The mean value of the maximum sound level L_{Amax} was analogously calculated

$$L_{Amax} = 10\log\left(\frac{1}{n}\sum_{i=1}^{n} 10^{0,1L_{Amax,i}}\right) \tag{4}$$

Calculated values are given in Table 1. The first two columns give the monitor number and name. Column 3 shows the average number of flight operations *N* at nighttime. The average L_{AE} and L_{Amax} are given in column 4 and 5, respectively.

Columns 6 and 7 shows respectively the average number N_L and the average level $L_{Amax,L}$ of “loud events”. The loud events include the flight operations which A-weighted maximum sound level $L_{AmaxF} \geq 70$ dB.

In column 8 the coefficient *p* is given, which is a ratio of maximum number of flight operations in a half hour at the nighttime to the overall number of flight operations at night.

Table 1. Noise parameters at the Chopin Airport monitors at the nighttime

Monitor	Name	N	L_{AE}	L_{Amax}	N_L	$L_{Amax,L}$	p
1	2	3	4	5	6	7	8
P01	Załuski	18.4	93.6	87.3	17.6	87.4	0.29
P02	Piaseczno	6.8	80.2	70.2	1.4	74.3	0.23
P03	Mysiadło	14.5	83.8	74.5	10.6	74.6	0.24
P04	Onkologia	6.0	88.8	79.3	5.3	79.8	0.32
P05	Meral	5.5	84.5	74.0	4.3	77.1	0.36
P07	Kossutha	1.3	82.0	72.0	0.7	74.5	0.35
P08	Ursus	16.8	83.5	73.3	10.1	74.6	0.28
P10	Piastów	13.9	78.5	66.9	0.7	72.2	0.25

The data refer to 2017 with the exception of P05 Meral, where the data from 2018 were included, when the number N_L of loud operations increased above 3.

The noise parameters were calculated for the whole year with the exception for P04, P05 and P07. Massive air traffic passes over these points only for a few weeks a year. For example at the P04 the flight operations are very unevenly distributed over individual months. In particular, in April 2017 a very large number of flights occurred (Figure 2). At night there were 472 flights, what corresponds to an average of 15.7 flights during one night. In the whole year the average number of flights at night was 1.7, while during of three consecutive most unfavorable months, the average was 6.0 flights per night.

As the annual number of takeoffs and landings in 2017 over P04 exceeded 6,000, according to PN-B-02151-3:2015-10 calculations should include all days and nights of the year. This means taking into account 1.7 flights during the night, while the average in April 2017 was nearly ten times higher. This also means not taking L_{Amax} into account, because the number of flights at night did not reach N = 3, and consequently, the lack of the protection against awakening caused by loud flight operations repeated over one night.

As a compromise for the P04, P05 and P07 monitors the noise parameters have been calculated taking into account three months when the largest air traffic is observed, like in the airports with the number of start - landing pairs up to 3000 a year according to PN-B-02151-3:2015-10. For such airports averaging the number of operations throughout the whole year for the all runways would lead to understating the noise rating in relation to the real noise annoyance in certain areas around the airport. The selection of the averaging interval should apply to individual runways, not to the entire airport.

The noise monitors are located at distances from 1 to 9 km from runway thresholds. As can be seen from Table 1 the largest noise parameters are at P01 located closest to the airport. As the distance from the airport increases, L_{AE} and L_{Amax} decrease. The spread among the noise monitors equals to 15 dB for L_{AE} and over 20 dB for L_{Amax}.

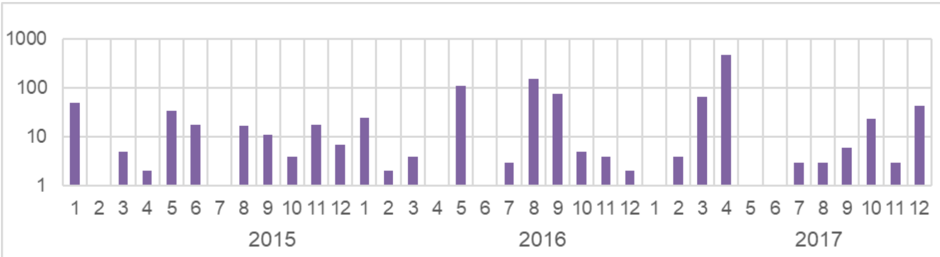

Figure 2. The nighttime flights number in months at monitor P04 - Onkologia

The average number N ranged from 1.3 to 18.4 during the 8 hours of the night. Close to the airport, the number of operations is greater because the individual inbound and outbound tracks are connected.

Between one quarter and over one third of all operations at night happens during the busiest half hour. Values of the coefficient p are the highest in the directions on which the number of flights is the smallest.

The mean value of the $L_{Amax,L}$ exceeds 70 dB at all sites. The number of loud operations is at least 3, with the exception of P02, P07 and P10, which are outside the branching of outgoing tracks.

External noise indexes were calculated from the Table 1 data. The A-weighted equivalent sound level $L_{Aeq,\ out,\ 8h}$ (according to PN-B-02151-3: 2015-10) was calculated from the formula

$$L_{Aeq,out,8h} = L_{AE} + 10\lg\frac{N}{8 \cdot 3600} \quad (5)$$

The A-weighted equivalent sound level for half an hour with the largest number of operations $L_{Aeq,out,1/2h}$ (according to PN-B-02151-02: 1987) is given by

$$L_{Aeq,out,\frac{1}{2}h} = L_{AE} + 10\lg \frac{pN}{0{,}5 \cdot 3600} \tag{6}$$

4. Internal noise level

Noise requirements have been collected for rooms (bedrooms, great rooms, multi-purpose rooms and the like) in residential buildings at nighttime, resulting from Part 2 and Part 3 of PN-B-02151 in Table 2.

Table 2. Noise evaluation criteria in rooms in residential buildings at nighttime

Standard	Criterion
PN-B-02151-3: 2015-10 („Part 3")	reference level $L_{Aeq,in,8h}$ = 25
PN-B-02151-3: 2015-10 („Part 3")	reference level $L_{Amax,in}$ = 50 if $3 \le N_L \le 5$ reference level $L_{Amax,in}$ = 45 if $N_L > 5$
PN-B-02151-02: 1987 („Part 2")	permissible level $L_{Aeq,in,1/2h}$ = 30

5. Required attenuation of aircraft noise

The required attenuations $D_{A,min}$ to fulfill the requirements from Table 2 are calculated below. It was assumed that aircraft noise is the dominant noise in the environment.

Using the formulas (5) and (6) and criteria of internal noise from Table 2, the required attenuation has been expressed as follows:

$$D_{Aeq,8h} = L_{AE} + 10\lg \frac{N}{28800} - L_{Aeq,in,8h} \tag{7}$$

$$D_{Amax} = L_{Amax,L} - L_{Amax,in}(N_L) \tag{8}$$

$$D_{Aeq,\frac{1}{2}h} = L_{AE} + 10\lg \frac{pN}{1800} - L_{Aeq,in,1/2h} \tag{9}$$

where:

for $N_L < 3$ $L_{Amax,in}(N_L)$ is not applicable (n/a)
for $3 \le N_L \le 5$ $L_{Amax,in}(N_L) = 50$
for $N_L > 5$ $L_{Amax,in}(N_L) = 45$

The results of the required attenuation calculations for monitoring sites are given in Table 3 where also the differences in requirements are shown.

The typical value of noise attenuation by an external envelope for residential buildings is approximately 30 dB. As shown in Table 3, the required attenuation is about 30 dB at the monitoring points near the airport. In P01, it exceeds 40 dB.

It is seen that the equivalent sound level according to the Part 2 creates higher requirements than the long-term equivalent sound level according to the Part 3. The difference in the required attenuation is from 0.6 to 2.6 dB.

Table 3. Required attenuation of aircraft noise in buildings at monitoring sites

site	$D_{Aeq,8h}$ [dB]	D_{Amax} [dB]	$D_{Aeq,1/2h}$ [dB]	$D_{Aeq,1/2h}$ - $D_{Aeq,8h}$ [dB]	D_{Amax} - $D_{Aeq,1/2h}$ [dB]	D_{Amax} - $D_{Aeq,8h}$ [dB]
P01	36.7	42.4	38.3	1.6	4.1	5.7
P02	18.9	n/a	19.6	0.6	n/a	n/a
P03	25.8	29.6	26.6	0.8	3.0	3.8
P04	27.0	34.8	29.0	2.0	5.8	7.8
P05	22.3	27.1	24.9	2.6	2.2	4.8
P07	26.2	29.6	27.6	1.5	2.0	3.4
P08	20.3	n/a	21.4	1.1	n/a	n/a
P10	18.9	n/a	19.6	0.6	n/a	n/a

Requirements concerning the attenuation of external noise resulting from the Part 2 of PN-B-02151 and from the Part 3 can be compared analytically. The difference between the requirements given by (9) and (7) indicates which standard is more demanding:

$$\delta_{Aeq} = D_{Aeq,\frac{1}{2}h} - D_{Aeq,8h} = 10\,\mathrm{lg}(16p) - 5 = 10\,\mathrm{lg}(p) + 7 \tag{10}$$

If a number of flights in each interval half-hour long is the same, then $p = 1/16$. In this case $\delta_{Aeq} = -5$ dB. If all flights take place in only one half hour, then $p = 1$ and $\delta_{Aeq} = 7$ dB.

For $p = 0.20$, the requirements of the both standards are equal. For p like in Table 1 the requirements of the Part 2 are 0.6 to 2.6 dB higher than those of the Part 3.

When the number of loud events is minimum 3, the requirements concerning $L_{Amax,out}$ are bigger than these concerning with L_{Aeq}. Values of D_{Amax} are higher by 2.0 to 5.8 dB than $D_{A,½h}$ and by 3.4 to 7.8 dB higher than $D_{A,8h}$.

For N > 5 the difference D_{Amax} - $D_{A,8h}$ equals to

$$\delta_{A(max-eq)} = D_{Amax} - D_{Aeq,8h} = L_{Amax,L} - L_{AE} - 10\mathrm{lg}(N) + 24{,}6 \tag{11}$$

The difference $\delta_{A(max-eq)}$diminishes when number of flights grows. When N will increase to the maximum predicted number 40, $\delta_{Amax/eq}$ can decrease to zero. In this case, the required attenuation connected with L_{Amax} will no longer matter.

6. Conclusions

The study compares the minimum attenuation of aircraft noise by the building envelope which results from the standards that currently apply [10]. The comparison was carried out for bedrooms, multi-purpose rooms and the like and concerned the nighttime. Data concern the locations of monitors belonging to the noise monitoring system of the Chopin Airport Warsaw

The minimum of noise attenuation by the building envelope, resulting from of PN-B-02151-02:1987, differs from the minimum according to PN-B-02151-3:2015-10.

The highest required attenuations occur in places where the average number of operations at night is not less than 3. In such case required attenuation is determined by the long-term maximum sound level L_{Amax}. The requirements related to L_{Amax} are 2.0 to 7.8 dB higher than those associated with L_{Aeq}. This is in line with the principle of preventing waking up during the night caused by noisy acoustic events [11].

If the number of aircraft operations increases to the maximum allowed number 40 during one night, the difference between required attenuation related to L_{Amax} and related to L_{Aeq} may decrease to zero. In this case, the requirements connected with L_{Amax} will no longer be relevant and the requirements related to L_{Aeq} will be decisive.

Between the requirements related to L_{Aeq} a bit higher requirements are set by PN-B-02151-02:1987 than by PN-B-02151-3:2015-10. With regard to the data examined, the replacement of PN-B-02151-02:1987 by PN-B-02151-3:2015-10 reduces the required attenuation by 0.6 to 2.6 dB. It should be remembered, however, that according to the Part 3, the equivalent sound level of aircraft noise is averaged over three months or a whole year, whereas the equivalent sound level according to the Part 2 may be referred to the busiest half-hour which happened only in one night. This is not a problem on tracks where the number of flights does not change significantly overnight. However, in the case of the tracks with an unequal distribution of the number of flights on a timeline, the problem arises as to whether the protection of buildings against noise occurring for several weeks a year should be as good as if the noise occurs every night. On the other hand, if aircraft noise occurs only for a month in a year, but its equivalent level is calculated in relation to the whole year, the average annual noise level will be lower by 10.8 dB. Lowering the required attenuation in buildings by such size will undoubtedly reduce the quality of rest at night.

However, it should also be noted that the requirements of PN-B-02151-3:2015-10 are only valid during the construction process. If transport noise will increase during the use of building, the lack of PN-B-02151-02:1987 will mean the lack of formal and legal possibility of assessment of this noise in the building. In particular, this problem will occur for buildings on limited-use areas, for which the requirements for protection against aviation noise are formulated as the permissible noise level in a room. This applies to almost all the biggest areas of limited use of civil and military airports in Poland. The only Polish Standard which gives the permissible noise level in rooms is PN-B-02151-02:1987. The alternative standard PN-B-02151-3:2015-10 is assigned only to the building process. Besides, it does not specify the permissible noise level in rooms, but gives so called reference levels, i.e. numerical values to be used in the calculation of the required acoustic insulation of partitions, but they cannot be used to assess the noise occurring in rooms.

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