Laboratory studies of protection against propagation of impact noise from staircases

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Summary

Reducing the propagation of impact and structure-borne sound from the stairwell to the adjacent protected areas requires the application of special protection in the form of flexible mounting the staircase elements as landings and flights of stairs in the construction of the building. The elastic interlayers used for separating the construction should be specified by the acoustic properties based on laboratory tests. Unfortunately, there are no international standards for this kind of measurements. In Acoustic Laboratory of ITB, numbers of solutions of acoustic protection of staircases have been investigated. The study has used a standardized method of measuring the sound impact level and has been conducted on the models of parts of a staircase in a 1:1 scale, without and with anti-vibration protection. Applying the method of testing similar to the test methods for floating floors, ΔL_w indicators determining impact sound reduction of particular solutions (flexible mounting of landing in the wall and flexible supports of the stair flights at the landings) have been determined. In studies, the different load of the staircase elements, leading the various tensions in the elastic interlayer, has been taking into account.

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1. Introduction

The legal requirements for sound insulation in buildings also include impact sounds levels of noise transmitted from staircases to the protected premises.
Introduced in some European countries acoustic classes make these requirements more and more restrictive and difficult to meet.
There are many manufacturers that offer all sorts of insulating material intended to be used in stairwells.
Protection materials can be divided into two basic groups: acoustic insulation of landing fitting in the wall of the stairwell and acoustic insulation of support of stair flights at landings.
In general, it is assumed that the performance of this kind of protections is described with the weighted reduction of impact sound pressure level ΔL_w, similarly as in the case of floor coverings. There is a lack of standard specifying the conditions and methods of measurement in the laboratory, adapted to specify the characteristics of resilient supports dedicated to use in staircases.

2. Laboratory tests for evaluation of reduction of impact sound pressure level by acoustic protection of staircases

Measurement methods of reduction of impact sound pressure level by acoustic protection of staircases shall comply with the following conditions:
a) the design of the test facility should be strictly determined so that the studies carried out in different laboratories of the same element give the same results (ΔL and ΔL_w),
b) values of ΔL and ΔL_w, evaluated under laboratory conditions, should enable to calculate the weighted impact sound level resulting from the transmission of impact sound from staircases in building (L'_w).
These conditions in respect of floor coverings are met by: specifying the test facility and the

standard floors (massive and light), on which the measurements of ΔL are carried out (acc. to EN ISO 10140-1[1], EN ISO 10140-3[2] and EN ISO 10140-5[3]), determining the method of calculating the index ΔL_w (EN ISO 717-2[4]) and calculating the index L'_{nw} of real floor with the floor covering characterized by ΔL_w (EN 12354-2[5]).

Many laboratories (including Acoustic Laboratory of ITB), carrying out assessment of the acoustic quality of resilient stair supports, apply the test facility, which can be described as simplified model in scale 1: 1 of the staircase adjacent to protected areas (Figure 1).

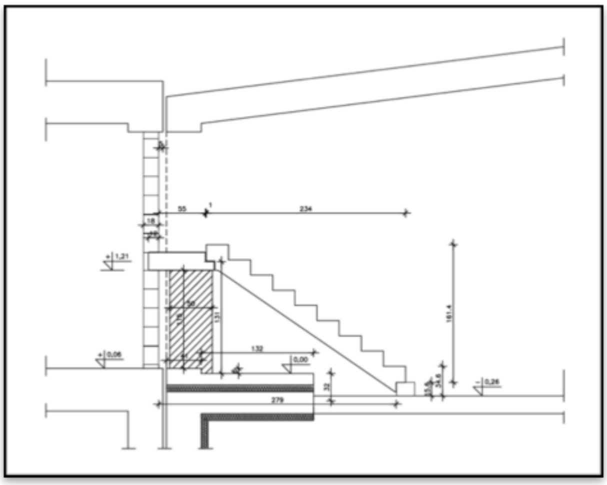


Figure 1. Model of the flight of stairs supported on the landing in laboratory

The sending room is separated from the receiving room by the wall, in which the stair landing connected with the flights of stairs is fixed. Depending on the type of protection, the model can also include only the landing plate located in the wall that separates the test rooms.

Usually, as a source of impact sound, the standard tapping machine is used. The test procedure is similar to measurements of the normalized impact sound pressure level applied for floor covering according to EN ISO 10 140 -1:2010, Annex H. Evaluation of the reduction of impact sound pressure level ΔL is based on the measuring of impact sound pressure levels in the receiving room in two situation: when there is no acoustic protection (stairs are rigidly connected to the separating wall) and when the resilient supports are used.

$$\Delta L = L_{n0} - L_n \qquad (1)$$

ΔL - the reduction in impact sound pressure level after applying the sound protection, dB

L_{n0} - the normalized impact sound pressure level in the receiving room during the work of the standard tapping machine on the stairs element (without the acoustic protection), dB

L_n - the normalized impact sound pressure level in the receiving room during the work of the standard tapping machine on the stairs element (with the acoustic protection), dB

The value of L_{n0} is therefore the reference level, used to assess the acoustic quality of the insulation material.

Determine the level of L_{n0} during the work of tapping machine at the appropriate element of the staircase model (landing, stair flights) without acoustic protection means the use of the full analogy to the measurement of acoustic quality of floors.

The calculated value of ΔL depends on this reference level L_{n0} as well as the design of the wall between the test rooms, which are connected to staircase model elements and the its technical characteristics (the surface and the thickness of landing, construction of stairs flight). However, the effect of these factors is much smaller than the method by which the level L_{n0} is evaluated.

Based on the test reports of different laboratories, it appears that a wall between the rooms are made of calcium silicate blocks with a thickness of 18-24 cm and density 1800-2000 kg/m^3. There are also differences in the dimensions of the landings.

In research work of Hochschule für Technik Stuttgart [6,7] a new method of determining the level of L_{n0}, dedicated for predicting the sound transmission in building, is proposed. The excitation of the wall between test rooms without the stairs protection is made with using the special source with similar force as the standard tapping machine. The level of impact sounds in the receiving room, in this case, is bigger than in the case of excitation by standard tapping machine, working on the element of the staircase. In consequence, the values ΔL and ΔL_w characterizing sound protection are larger. The several examples of this issue are explained in point 3.

In order to obtain test results comparable between different laboratories, it is necessary to:

a) closely determine the parameters of the test facility comprising as:

- type of the wall between the test rooms
- technical data of the staircase model elements (landing, flight of stairs)

b) define the way of impact noise excitation in determining the value of impact sound level L_{n0}

c) clarify the method of calculation of ΔL_w (if we accept, as before, the analogy to the method of calculation used for the floors)

3. Influence of L_{n0} evaluation method on performance of acoustic protection

Based on available measurement data of one of the German laboratories, the values ΔL_w of several resilient staircase supports have been evaluated and compared using various values of L_{n0}.

In reports of that laboratory, the values of L_{n0}, obtained during electromechanical excitation of the wall have been specified. In addition, L_{n0} values measured during the work of standard tapping machine placed on the landing, rigidly mounted in the wall between the test rooms have been done.

L_{n0} curves as a function of frequency for both cases of excitation are given in Figure 2.

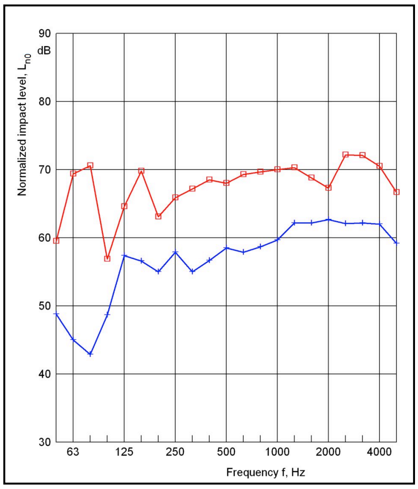


Figure 2. Reference impact sound level L_{n0} [6] measured on:

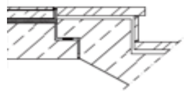
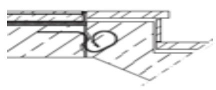
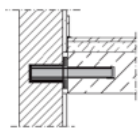
- □ reference wall of 24 cm CaSi with density 2000 kg/m^3, source – electrodynamic tapping machine
- + rigidly connected landing, source - standard tapping machine

The difference in terms of index $L_{n0,w}$ is 8 dB. Differences between values ΔL_w depending on the accepted reference level L_{n0} are given in table 1.

Using the method proposed by Hochschule für Technik Stuttgart (electrodynamics stimulation of the separating wall in which the staircase model without protection is mounted) leads to values of ΔL_w which are 9-14 dB higher than in situation in which the measurements are made with the standard tapping machine working on a specific element of the staircase model.

Due to the too small number of data and information, we do not judge this method. It is only to point out that changing the method of determination of the reference level results in a fundamental change in the value ΔL_w used to characterize the performance of acoustic protection.

Table 1. A comparison of the value ΔL_w depending on the adopted methods of measurement L_{n0}

Kind of protection	Weighted reduction of impact sound pressure level ΔL_w in relation to the evaluation method of L_{n0}, dB	
	Method A	Method B
Flexible support of the flights of stairs on the platform (various types) 	27 - 28	40
Connection of the flights of stairs with the platform through the special connectors (various types) 	28-30	42
	28	39
	25	37
The framing attachment in the wall using the "insulation boxes" (various types) 	29	38
	27	37
	28	39
	25	37
	27	37

Method A

L_{n0} – standard tapping machine (stm) on stairs element (without protection)

$\Delta L = L_{n0} - L_n$

$L_{n,r,0}$ – relates to stm (EN ISO 717 – 2)

Method B

L_{n0} – electrodynamics stimulation of separating wall (without protection), $L_{n0(wall)}$

$\Delta L^* = L_{n0(wall)} - L_n$

$L_{n,r,0}$ – relates to stm (EN ISO 717 – 2)

It is possible that the evaluation of ΔL_w used in method B is not strictly the same as proposed by HTS. This may be due to the quite complicated way of determining the impact sound reduction index used in the standard EN ISO 717-2.

Differences between ΔL_w values decrease to 1-2 dB if, in case of the wall's stimulation, the reference wall instead of the reference floor would be adopted ($L_{n,r,0} = L_{n,r,0\ (wall)}$, $L_{n,r,0,w} = L_{n,r,0,w\ (wall)}$).

4. Examples of laboratory tests of staircases protection carried out in the Acoustic Laboratory of ITB

Measurements of acoustic properties of resilient stair supports were conducted in the Acoustic Laboratory of ITB in the years 2006-2009. Tests included the insulating elements used in fitting of landing to the wall and antivibration pads used in support space of stairs flights on landing.

Test facility was prepared in the laboratory consisting of two completely decoupled rooms. Between the rooms, from the side of receiving room (behind dilatation) a calcium silicate wall with thickness of 18 cm and density 1800 kg/m^3 was built. Depending on the kind of protection, the landing (16 cm prefabricated reinforced concrete plate with dimensions 2, 5 m x 1, 5 m) or the landing connected to the stairs flight was mounted in this wall. Pictures of both cases are shown in Figures 3 and 4.

Elements of the model were fixed in the sending room (separated by dilatation from the side of the receiving room), on supports or directly on the floor, through flexible spacers.

Before the start of measurements, it has been examined whether the sound pressure level measured in the receiving room comes exclusively from impact sound. This was done by measuring the airborne insulation between test rooms and calculations taking into account the sound level in the sending room during the work of tapping machine set on the model of the staircase.

Impact sound pressure level in the receiving room has been specified in relation to the investigation of the model. Tapping machine was set in 3 places on the platform and on 3 different steps of the stairs. Examples of the results of the measurements are shown in Figure 5. Values of impact sound pressure levels L_{n0} and weighted impact sound pressure levels $L_{n0,w}$ are slightly larger in case of tapping machine position on the landing than on the flights.

Impact levels L_{n0}, measured in the receiving room during the work of the standard tapping machine put on the landing without acoustic protection, differ just slightly from analogous values according to the report from the German laboratory. Slightly higher values of L_{n0} and $L_{n0,w}$, defined in studies carried out in the laboratory of ITB, result from a smaller surface mass of the wall and slightly smaller thickness of landing plate.

Figure 3. Model of landing connected to the separating wall between the test rooms in Laboratory of ITB (left: rigidly, right: by resilient elements)

Figure 4. Stairs flight supported on the rigidly connected landing to the separating wall between the test rooms in Acoustics Laboratory of ITB

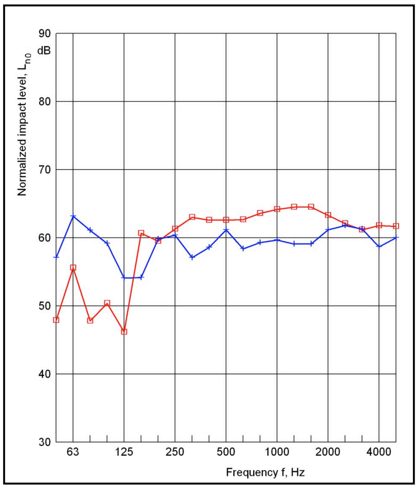


Figure 5. Impact sound pressure levels L_{n0} (without acoustic protection) depending on the location of standard tapping machine (results of Acoustics Laboratory of ITB)

□ on the landing

+ on the flight of stairs

Much larger values of L_{n0} and $L_{n0,w}$ in German laboratory are observed at the electrodynamics activation of the wall. The corresponding statement is shown in Figure 6.

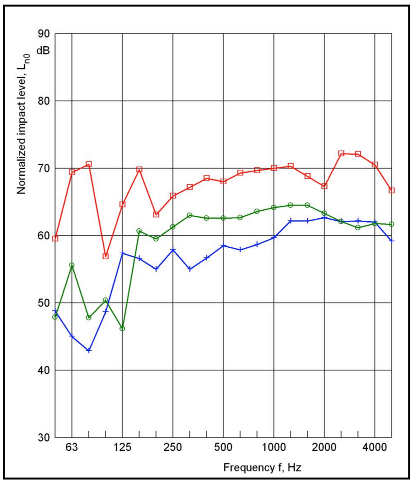


Figure 6. Comparison of the values L_{n0} according to German and Polish studies

- □ reference wall of 24 cm CaSi with density 2000 kg/m^3, source – electrodynamics tapping machine [6]
- \+ rigidly connected landing, source – standard tapping machine [6]
- ⊙ rigidly connected landing, source - standard tapping machine [results of ITB]

The possible effects of static load per a single resilient element should also be given into account. Changing the static load has a little impact on the impact sound levels L_{n0} and $L_{n0,w}$ (see Figure 7).

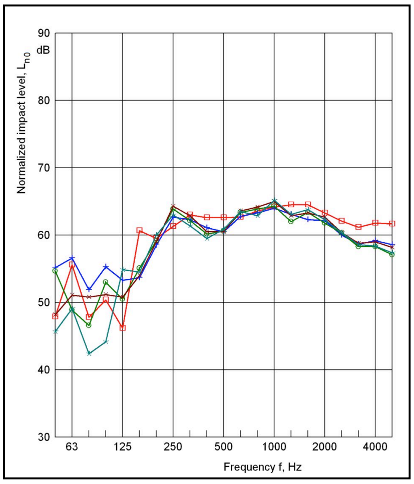


Figure 7. Impact sound pressure levels L_{n0} (without acoustic protection) measured for different static loads of landing (results of ITB)

□ 7.75kN (without load) + 12.1 kN

⊙ 16.2 kN × 20.4 kN ✳ 24.7 kN

The influence of load changes on ΔL_w may be larger, depending on the type of protection and type of flexible materials.

5. Conclusions

1) There is an urgent need to develop standard method for testing of products used to acoustic protection of staircases. Such a method should precisely define measurements conditions including the type of wall, in which the elements under test is fixed and the construction of the model of the staircase (thickness and surface, the design of the stairs platform). This is required to be able to compare test results from different laboratories.

2) The method should precisely define test facility construction (staircase mock-up) for testing of two types of resilient elements:

- platform support elements installed in a wall,
- flight of stairs supports on a landing.

3) A major issue that requires further research is the way of specifying the reference levels of L_{n0} – determined for the model without insulation elements and L_{nr0} –level for reference floor or reference wall. If the results of such studies indicate the advisability of adopting the method of the electromechanics excitation of the separating wall, the consequences on the market can be expected. It cannot, in fact, leads to a situation in which the same product would be described by two significantly different values ΔL_w (depending on the applied test method). In such a situation, it would be necessary to define at least the approximate relationship between these values.

4) Determined, on the basis of laboratory tests, ΔL_w level of a staircase protection, should make it possible to predict the impact sound pressure level in a room adjacent to the stairwell in the building. For this purpose it is necessary to develop a calculation method similar to the method used for the floors with floor coverings (acc. to EN 12354 – 2).

References

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