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Model for simplified calculation of composite slabs sound insulation characteristics in the presence of impact noise

Aleksandar Kirechev[1]
[1]Faculty of Telecommunications,
Technical University – Sofia,
8 Kl. Ohridski 8 Sofia 1000,
BULGARIA.

Abstract: *Calculations of composite slabs sound insulation characteristics is very important not only as theoretical researches, but mainly in practical tests in the effort to choose suitable characteristics of a tested structure, combining different insulation materials and changing their position in the tested structures. The existing methods and appropriate models for calculation of composite slabs sound insulation characteristics are complex and time consuming. Therefore, the goal of this article is propose and investigate a model of simplified calculations of composite slabs sound insulation characteristics to speed the appropriate decision when testing and choosing the suitable composite insulation structures and speed the comparison of the effect of placing different materials, combining them in different structures. As theoretical basis in the development of the proposed model are used fundamental for insulation Cremer's theory, the international standard for insulation EN ISO 12354-2:2017 and professional software INSUL. In the experiments are calculated the impact sound insulation index using composite slab reinforced with profiled steel decking covered with lightweight underfloor heating and the possible improvement with additional damping layer under the underfloor heating. The experimental results presented with tables and graphics show the work of the proposed model and its abilities to be used in practical implementations of composite insulation materials and structures tests.*

Keywords: *slab sound insulation characteristics, impact sound pressure level, composite slab, dynamic stiffness*

I. Introduction

The Protection against noise is one of the six essential requirements, which have been stated in the European Construction Product Directives [1]:

- mechanical resistance and stability;
- safety in the case of fire;
- hygiene, health and the environment;
- safety in use;
- protection against noise;
- energy economy and heat retention.

The building constructions must be designed and built in such a way that the noise perceived by the occupants or people nearby is kept down to a level that will not threaten their health and will allow them to sleep, rest and work in satisfactory conditions.

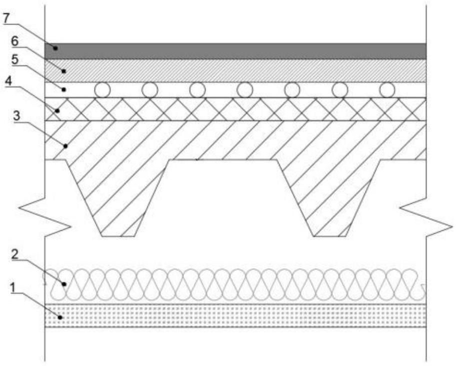
The main factors, that define the acoustical quality of constructions in buildings, are airborne and impact sound insulation between rooms, airborne sound insulation of facades, reverberation time of rooms and noise level caused by technical installations.

In this paper are consider only the impact sound insulation and in particular of impact sound insulation of composite slab reinforced with profiled steel decking lightweight underfloor heating. The goal is to propose theoretically and test experimentally a suitable model for simplified calculation of composite slabs sound insulation characteristics in the presence of impact noise.

II. Predictive method for simplified calculations of impact sound insulation characteristics with the proposed model

In order to present in predictive form the model of simplified calculations of the weighted normalized impact sound pressure level first is proposed to calculate the weighted normalized impact sound pressure level of the composite slab reinforced with the model of profiled steel decking (Fig.1) Then is calculate the reduction of impact sound pressure level of addition lightweight underfloor heating.

Figure 1 Details of the generalized model of the composite slab, reinforced with profiled steel decking with lightweight under floor heating; 1. Suspended celling of Gypsum board; 2. Mineral wool; 3. Composite slab reinforced with profiled steel decking; 4. Heat and sound insulation layer of EPS; 5. Pipes for under floor heating; 6. Screed made of calcium-sulfate; 7. Parquet



A. Normalized impact sound pressure level of the composite slab reinforced with profiled steel decking

In order to calculate the normalized impact sound pressure level of composite slab reinforced with profiled steel decking we will use the procedure of European standard EN 12354-2 which use simplified models to estimate the acoustic performance of buildings [2]. The models, that the standard use is passed on the Cremer's theory of point force excitation, and so can used to evaluate vertical impact noise radiation for massive, rigid homogeneous construction [3] and [4].

In order to calculate the normalized impact sound pressure level we will use the following equations:

$$L_n = L_F + 10\lg\frac{\mathrm{Re}(Y)\sigma}{m'[1sm^2/kg^2]} + 10\lg\frac{T_s}{[1s]} + 10{,}6dB, \quad (1)$$

where L_F is the force level of tapping machine, m' is the mass per unit area and $\mathrm{Re}(Y)$ is the real part of the floor mobility, σ is the radiation factor for free bending waves, T_s is structural reverberation time. The radiation factor for free waves and the structural reverberation time is calculated accordance with ISO 12354-1:2017, Annexes B and C [5];

For homogeneous floor constructions the equivalent weighted normalized impact sound pressure level $L_{n,eq,0,w}$ is calculated using empirical equation and use the mass per unit area m'. For m' between 100kg/m^2 and 600kg/m^2 the following equation is given:

$$L_{n,eq,0,w} = 164 - 35\lg m'. \quad (2)$$

B. Weighted reduction of impact sound pressure level of addition lightweight underfloor heating

In order to calculate the reduction of impact sound pressure level of addition lightweight underfloor heating we will use the procedure of ISO 12354-2:2017 Annex C for floating floor screed made of calcium-sulfate [6]:

$$\Delta L = 30\lg\frac{f}{f_0}, \quad (3)$$

where f octave or third octave band center frequency, f_0 is the response frequency of the system given by:

$$f_0 = 160\sqrt{\frac{s'}{m'}}, \quad (4)$$

where s' is the dynamic stiffness per unit area of the resilient layer in accordance with EN 29052-1 measured without any pre-load and m' is the mass per unit area of the floating floor [7].

According to EN ISO 717-2 in order to calculate the weighted reduction of impact sound pressure level ΔL_w we have to use the following equations [6]:

$$\Delta L_w = L_{n,r,0,w} - L_{n,r,w} = 78dB - L_{n,r,w} \quad (5)$$

where the $L_{n,r,w}$ is the weighted impact sound pressure level difference $L_{n,r}$ and it is given by:

$$L_{n,r} = L_{n,r,0} - \Delta L. \quad (6)$$

The $L_{n,r,0}$ is given by the EN ISO 717-2:2017 by the following table I [6].

Table I Reference impact sound pressure level

Frequency Hz	$L_{n,r,0}$ dB
100	67
125	67.5
160	68
200	68.5
250	69
315	69.5
400	70
500	70.5
630	71
800	71.5
1 000	72
1 250	72
1 600	72
2 000	72
2 500	72
3 150	72

C. Weighted reduction of impact sound pressure level of addition lightweight underfloor heating and addition sound insulation layeeir

In order to calculate the result when adding the addition sound insulation layer we will use the equation provided for dynamic stiffness per unit area of two or more resilient layers:

$$s'_{tot} = \left(\sum_{i=2}^{n} \frac{1}{s_i'} \right)^{-1} \quad (7)$$

where s_i' is the dynamic stiffness per unit area of the resilient layer I in accordance with EN 29052-1 [7].

D. Total impact sound pressure level

The total impact sound pressure level $L'_{n,w}$ is given by EN ISO 12354-2:2017 by the following equation [5]:

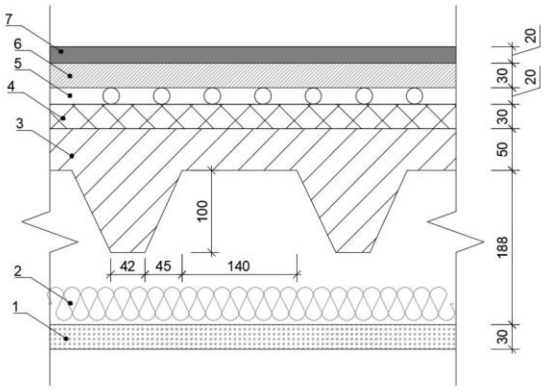
$$L'_{n,w} = L_{n,w,eq} - \Delta L_w + K, \quad (8)$$

where is the correction coefficient for homorganic constructions.

III. Experimental studies of the proposed simplified model for simplified calculation of composite slabs sound insulation characteristics in the presence of impact noise

The thinks and the parameters of the material that are used in the calculation of the impact sound insulation of composite slab reinforced with profiled steel decking with lightweight under floor heating are shown in details on Figure 2 with the appropriates dimensions of each part, corresponded to the generalized view shown on Figure 1.

Figure 2 Detail with the appropriates dimensions of the composite slab reinforced with profiled steel decking with lightweight under floor heating



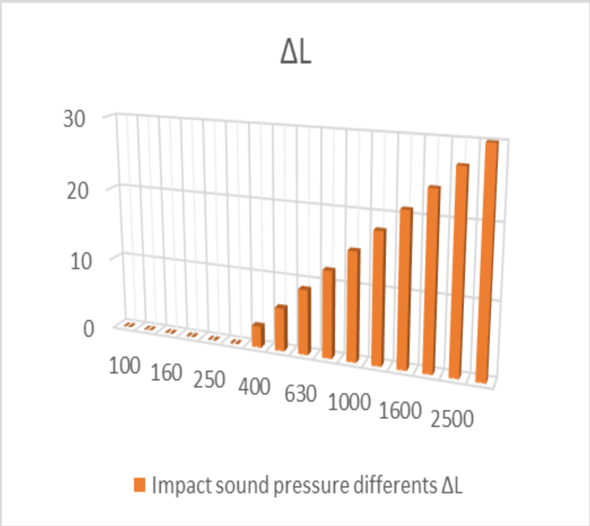
The characteristics of the material that will be used for the calculations are presented on Table II.

Table II Material properties

Material	Thickness [mm]	Mass per area [kg/m^2]	Dynamic stiffness [MN/m^3]
Calcium-sulfate screed	30	45	-
EPS layer	30	-	20
Addition sound insulation layer	16	-	13

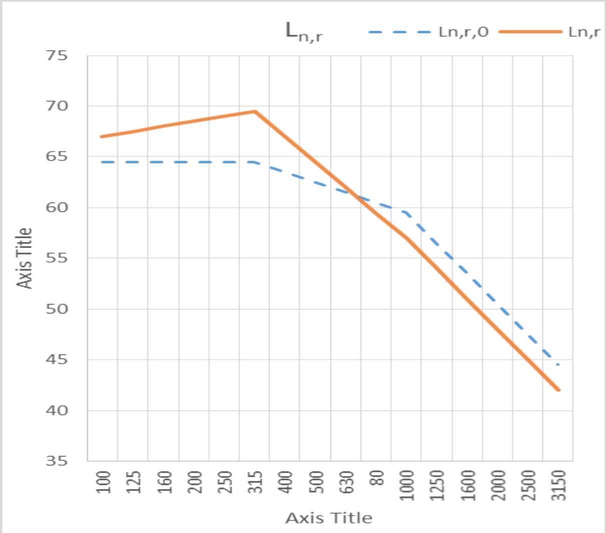
Following the equations (3) and (4) the response frequency of the system is calculated as follow: $f_0 = 336Hz$. The results for impact sound pressure different ΔL are given on Figure 3.

Figure 3 Spectrum of impact sound pressure different



Following the equation (6) are calculated the weighted impact sound pressure level difference $L_{n,r}$ and $L_{n,r,w}$ and are presented on Figure 4.

Figure 4 Spectrum of impact sound pressure different

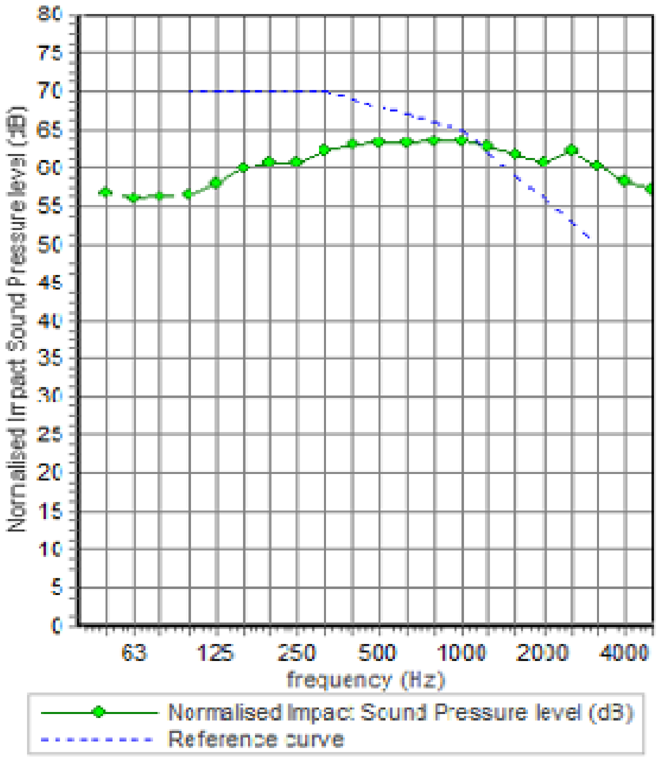


According to the equation (5) the weighted reduction of impact sound pressure level ΔL_w is calculated as follow:

$$\Delta L_w = 78dB - L_{n,r,w} = 78dB - 62dB = 16dB \quad (9)$$

The calculation of weighted impact sound insulation index $L_{n,w,eq}$ of a composite slab reinforced with profiled steel decking is calculated by software ISUL and the graph is shown on the Figure 5. And the calculated $L_{n,w,eq} = 68dB$ with correction coefficient of $C_1 = -9dB$

Figure 5 Graphic of a composite slab reinforced with profiled steel decking



The total impact sound pressure level $L'_{n,w}$ given by equation (8) is:

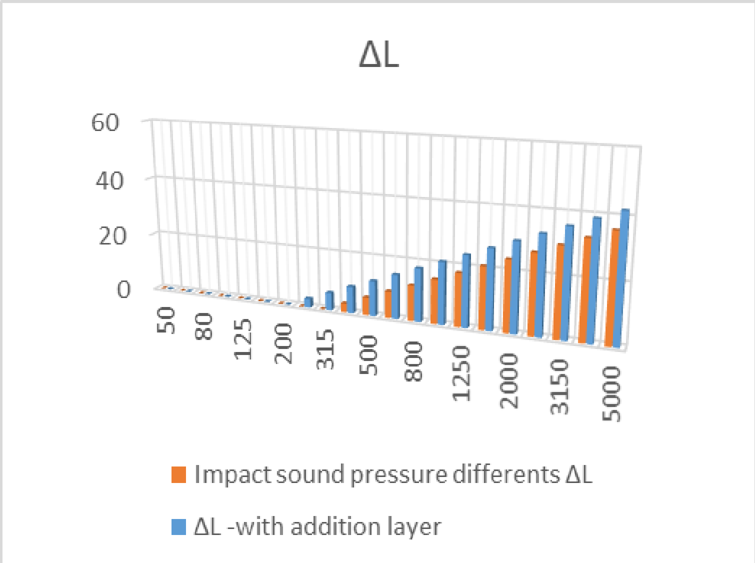
$$L'_{n,w} = 68dB - 16dB + 0 + 9dB = 61dB \quad (10)$$

In order to increase the impact sound insulation index we will add additional layer which has lower dynamic stiffness. To calculate the combined dynamic stiffness of the two materials s'_{tot} we use the equation (7).

The calculated combined dynamic stiffness is $s'_{tot} = 7.878MN/m^3$.

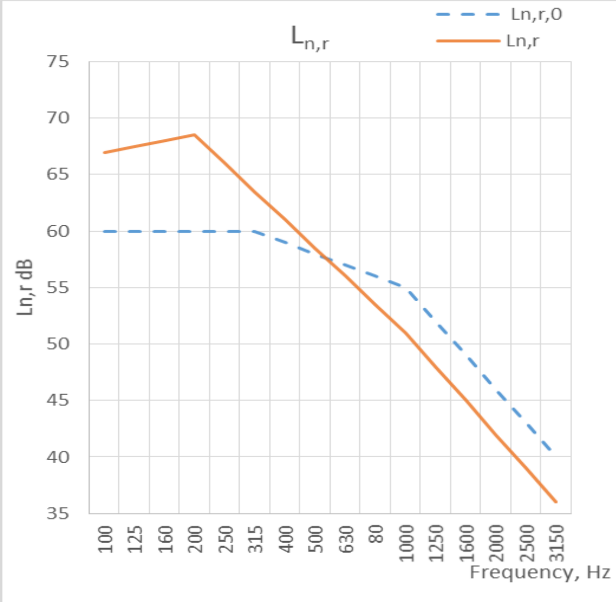
Then the response frequency of the system is calculated as follow: $f_0 = 211Hz$ and the results for impact sound pressure different ΔL is given on Figure 5.

Figure 6 Spectrum of impact sound pressure different



The calculated weighted impact sound pressure level difference $L_{n,r}$ and $L_{n,r,w}$ with addition layer is shown on Figure 7.

Figure 7 Graphic of impact sound pressure difference of the calculated detail



According to the equation (5) the weighted reduction of impact sound pressure level ΔL_w is calculated as follow:

$$\Delta L_w = 78dB - L_{n,r,w} = 78dB - 58dB = 20dB \tag{11}$$

The total impact sound pressure level $L'_{n,w}$ given by equation (8) is:

$$L'_{n,w} = 68dB - 20dB + 0 + 9dB = 57dB \cdot \tag{12}$$

IV. Conclusion

The analysis of the achieved experimental results in testing the proposed model for simplified calculation of composite slabs sound insulation characteristics can be summarized as follow:

- the speed of calculations is the main advantage of the proposed model related with the ability to calculate the impact sound insulation index faster than the existing more complex methods;

- although in the proposed model do not consider some parameters like boundary conditions, connections type, reverberation time of the two volumes, structural reverberation time of the construction and from which depend the accuracy, the advantage as speed of calculations make the proposed model applicable and preferred in practical applications, when is necessary quick to choose the structure of the tested composite insulation structures and in order to speed the comparison of the effect of placing different materials, combining them in different structures;

In further researches the proposed model for simplified calculation of composite slabs sound insulation characteristics in the presence of impact noise will be used in extended and modified form suitable to refine the modeling of new range of constructions such as raised floor and effect of adding different type of connection between suspended ceiling and concrete floor.

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Acknowledgments

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