Case studies in predicting airborne sound insulation in building

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ABSTRACT:
The paper overviews some aspects of predicting airborne sound insulation in building using simplified method. The aspects are: the K_{ij} values of different junctions, the estimation of flanking sound transmission through facades built of heat insulating brick blocks, the accuracy. The proposed extensions of the prediction method make the applicability of the procedure suitable to solve tasks of a wider range with known accuracy.

1. INTRODUTION

The subject of the present paper is to overview the predicting method of airborne sound insulation published in [1], used in building built of heavy constructions. The overview is made from a practical point of view: what can be solved, where are missing theoretical and practical elements, the necessary input data are available or not, what is the accuracy of the method and how the accuracy should be considered in the decisions of the process of planning.

2. BASIC CONSIDERATIONS OF THE USE OF ANY PREDICTING METHOD

2.1 The place of using predicting methods of airborne sound insulation in planning building

In out technical environment the most general place of using predicting methods of airborne sound insulation between rooms in building is the time of working out the "building permission plan". This is the plan where

- the main constructional system of the building is determined (for eg. skeleton frame building with infill walls made of limestone blocks);
- the groundplan and sessions are worked out, namely the connections between rooms are determined;
- the function of the property units and the rooms are given;
- etc.

These altogether mean the acoustical requirements and the main technical possibilities are fixed.

Using any prediction methods only those data can be considered as real input data, which are existing in this stage: the laboratory sound insulation of the building constructions (measured or predicted), the loss factor of the building construction, the geometrical data (lengths, sizes) the increment of sound insulation of wall linings, suspended ceilings and floating floors, etc..

2.2. Product data of the building constructions

Looking over the published data of building constructions it seems ideal constructions are the subjects of measuring airborne sound insulation as product data. The published technical data of the constructions cover only a part of those information, necessary to make a good prediction. Some of the missing technical details are listed below:

- the sound insulation of walls, made of brick, lime stone, gypsum or light concrete blocks depend also on the width of the vertical and bed joints and on the extent of filling these gaps with plaster; these data are missing;
- the walls are built in a frame construction, like in skeleton frame building; the solution of the upper edge of the wall is therefore of great importance; these data are not available;
- in real building conditions there are metal or plastic tubes of different size in the walls for electric, water and waste water lines; they are not reflected in the product information.

The loss factor of the studied wall can be considered much more a laboratory data than product data, as it cleared out from [2].

2.3. The vibration reduction index

Ref [1] determined values of the vibration reduction index of symmetric T and X form junctions, as functions of the relation of the specific masses of the coupled constructions. In Ref [3], [4] and [5] other forms of junctions were published, the way how to determine their vibration reduction index was given and also some data were presented. Also data of the vibration reduction index of hollowed walls were introduced.

In modern architecture, when the facade walls are not plain constructions, asymmetric T junctions occur in the reality - see example -. The way how to determine their K_{ij} values is the following:

- for symmetric junctions the difference of the direction averaged structural transmission $R_{ijsym,\gamma}$ and $K_{ij,symm}$ depends on the field data of the junctions: first of all the geometrical data and the loss factors are to be considered;

  $$C_{ij} = R_{ijsym,\gamma} - K_{ij} \qquad (1)$$
- for realistic combinations of thickness and materials, including brick, limestone, gypsum, concrete and light concrete elements C_{ij} can be calculated and using curve fitting it can be expressed as the function of the relation of specific masses, for symmetric junctions;

- C_{ij} can be considered to have the same function for asymmetric junctions, and after calculating the directional average structural transmission of asymmetric junctions, $R_{ijas,\gamma}$, K_{ij} for asymmetric junctions can be given also by regression method. The results of this calculation are given in Fig. 1.

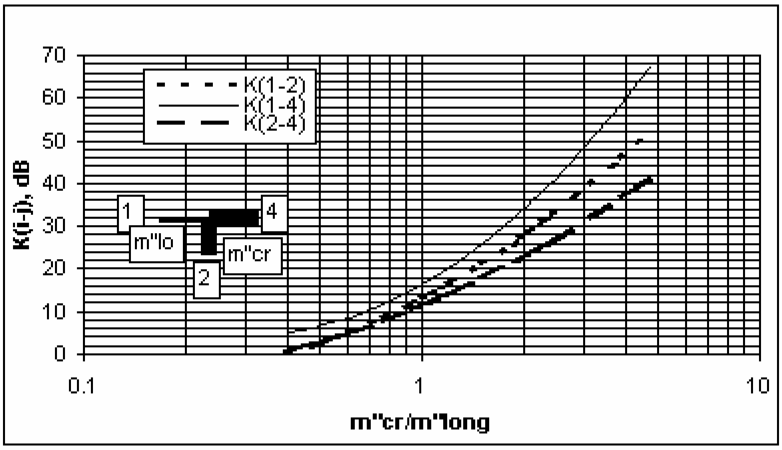


Fig 1. K_{ij} *of asymmetric T form junction*

There are traditional double wall constructions, made of gypsum, light concrete, or brick blocks the thickness of them is generally 6 - 10 cm. These double walls are coupled to other constructions (walls, floor slabs) with rigid junctions forming Π or double Π junctions. Theoretical investigations show they can be replaced by **T** or **X** junctions the way, summarized in table 1.

Table 1. *Solving junctions of double walls*

	Π junction	**T junction**	**Equivalent mass relation**
Form of junction	$m''_1 = m''_4$ 1 4 2 3 m''_2 m''_3	$M''_1 = M''_4$ 1 4 2 M''_2	
Direction of propagation	**1 - 4**	**1 - 4**	$\frac{m''_2 + m''_3}{m''_1} \to \frac{M''_2}{M''_1}$
	2 - 4	**2 - 4**	$\frac{m''_2}{m''_1} \to \frac{M''_2}{M''_1}$
	1 - 3	**1 - 2**	$\frac{m''_2}{m''_1} \to \frac{M''_2}{M''_1}$

In several practical cases flanking transmission should be considered not only through single but at least double junctions for the purpose to increase accuracy. It can be theoretically derived the resultant K_{ij} value can be determined by summing the K_{ij} of the junctions one after the other, if simplified calculation is carried out.

1:1 scale model investigations show, - the results were reported in [4] - the K_{ij} values of T form junctions, determined using the relation of the specific masses doesn't give correct values, in accordance with the measured ones, if the constructional element of the junction corresponding to the facade wall is made of heat insulating brick block. The accuracy of the calculation can be increased by using the measured values.

2.4. R_{ij} flanking sound reduction index

For the simplified prediction the R_{ij} flanking sound reduction index should be calculated according to eq. 2. as it is given in [1]. However if the facade walls are made of heat insulating brick blocks this solution leads to underestimate the flanking sound reduction index of the propagation paths through the facade junctions. In [4] this problem was studied and solved. Instead of the product data R_i and R_j measured in laboratory without flanking transmission, the sound reduction index, estimated from the specific mass should be used.

$$R_{ij} = \frac{R_i + R_j}{2} + \Delta R_i + \Delta R_j + K_{ij} + 10 * g \frac{S_s}{l_{ij} * l_0} \qquad (2)$$

3. CASE STUDIES

3.1. The considered variations

In the detailed calculations the simplified prediction method is considered. The acoustical source data are the measured sound reduction indexes in laboratory without flanking transmission. The loss factor was not considered. If measured sound reduction values are not available the estimation was made based on the specific masses.

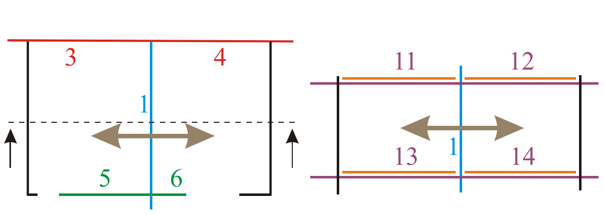
The constructional system of the studied building were the following :

- panel building of different panel constructions (examples 1 and 2);
- skeleton frame building with light concrete, limestone infill walls (examples 3 and 4);
- skeleton frame building with brick infill walls, heat insulating brick facade walls (examples 5 and 6);
- partition wall made of double gypsum or light concrete blocks (examples 7 and 8);

In the schematic figures showing the ground plan and the cross section red line and indexes 3, 4, 7 marks facade wall, blue line and indexes 1, 2, 8 marks the partition wall, green line and indexes 5, 6 marks the walls inside the flat, and black lines mark the walls having no primary effect in the flanking transmission. Purple lines and indexes 11, 12, 13, 14 mark the floor slabs and the additional orange line the floating floor if existing.

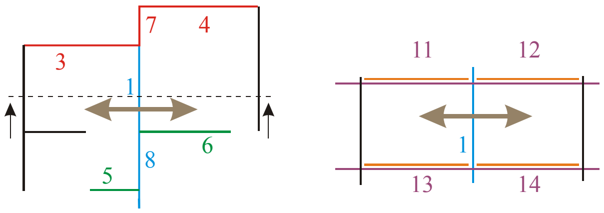
3.2. Panel building

In the considered examples the panels were made of either concrete (example 1 in Fig. 2.) or brick blocks (example 2 in Fig 3.). The junctions are symmetric, no heat insulating brick wall was used. The construction are homogenous. In example 2 double transmission through junctions is can be proposed to consider.



R'_w measured: 51dB, R'_w calculated: 52.7dB

Fig 2. *Example 1. Ground plan and section*

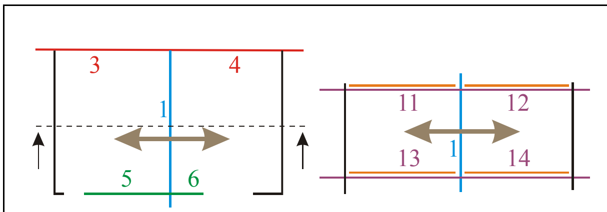


R'_w measured: 52dB, R'_w calculated: 50.8dB

Fig 3. *Example 2. Ground plan and section*

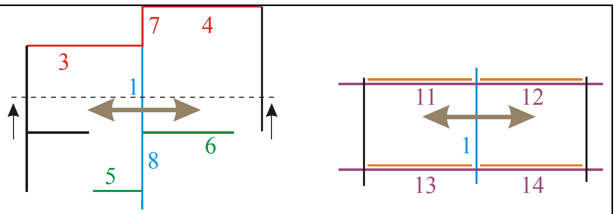
3.3. Skeleton frame building, limestone, light concrete infill walls

The ground plan and sections can be of more complex geometric arrangement. Therefore to create the model of calculation - this is shown in the figures - needs more considerations, based on the knowledge of structure borne sound propagation. The junctions are symmetric, the facade heat insulation is solved by external layers, having no effect on the flanking transmission. Two examples are shown in Fig. 4 and Fig 5.



R'_w measured: 53dB, R'_w calculated: 53.3dB

Fig 4. *Example 3. Ground plan and section*



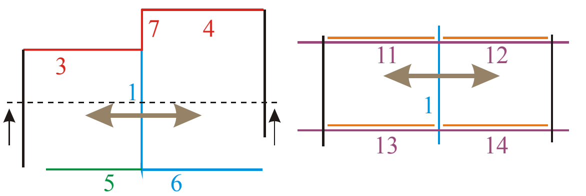
R'_w measured: 48.5dB, R'_w calculated: 49.9dB

Fig 5. *Example 4. Ground plan and section*

3.4. Skeleton frame building, brick block infill walls

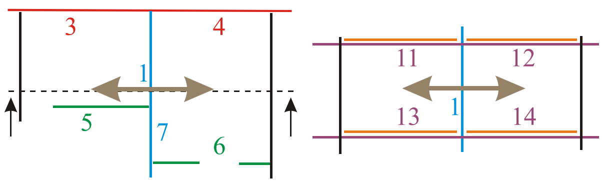
The ground plan and sections can be of more complex geometric arrangement. Therefore to create the model of calculation - this is shown in the figures - needs more considerations, based on the knowledge of structure borne sound propagation. The facade junctions are symmetric, or asymmetric depending on the ground plan. Asymmetric junction can occur both at the facade and also at the inner junction. If the weighted sound reduction index of the facade walls is taken according to [1], the calculated result is marked by *. Despite if the sound insulation of the facade wall is taken according to point 2.4. of the present paper, the calculated result is marked by **. The asymmetric T junction is solved according to Fig. 1. It can be seen very clearly the accuracy is mach better if the weighted sound reduction index of the facade wall is taken according to point 2.4.

The considered two examples are shown in Fig 6. and Fig 7.



R'$_w$ measured: 57dB, R'$_w$ calculated*: 51.3dB
R'$_w$ calculated**: 56.7dB

Fig 6. *Example 5. Ground plan and section*

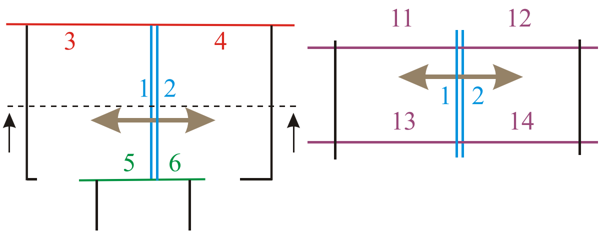


R'$_w$ measured: 57dB, R'$_w$ calculated*: 53.2dB
R'$_w$ calculated**: 55.8dB

Fig 7. *Example 6. Ground plan and section*

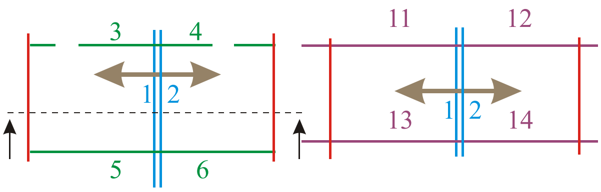
3.5. Partition walls made of double gypsum blocks with rigid junctions

Double walls occur in building of different constructional type, for eg. one can find examples in skeleton frame building, heavy walling system building, or insight cast walling building too. The junctions at the perimeter of the double wall are solved according to table 1. Two examples are shown in Fig. 8. and Fig 9. In the example in Fig 9. elements 3 and 4 are walls inside flat, while the walls 5 and 6 are partition walls between the flats. The facade walls doesn't play essential role in flanking transmission in the analyzed case.



R'$_w$ measured: 42.5dB, R'$_w$ calculated: 41.6dB

Fig 8. *Example 7. Ground plan and section*



R'$_w$ measured: 37dB, R'$_w$ calculated: 35.8dB

Fig 9. *Example 8. Ground plan and section*

4. ACCURACY OF THE PREDICTION METHODS

The result of the presented and some other examples are summarized in Fig 10. plotting the calculated and measured weighted sound reduction indexes. The standard deviation is less than 1.8. The calculated R'_w values are determined according to the proposals of the present material. If for eg. point 2.4. wouldn't have been considered the standard deviation would have been much higher, over 2.5.

In the set of data red rectangle belong to the group discussed in point 3.4., green circle belong to group 3.2., purple triangle belong to group 3.5. The others belong partly to group 3.3. or to walling system building.

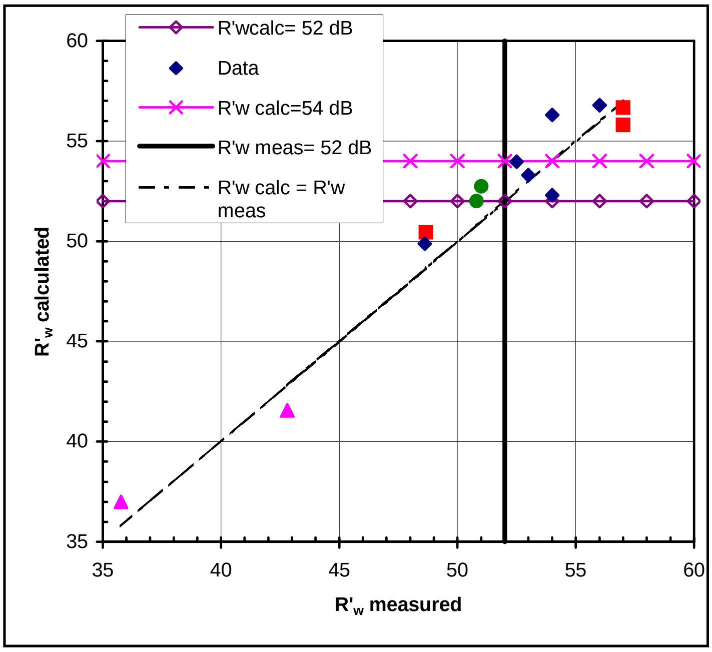


Fig. 10. *The accuracy of the simplified prediction*

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The standard deviation doesn't give the necessary support to the basic decisions when choosing or controlling building constructions from the point of view of fulfilling any requirements. The uncertainty of single estimate based on the standard deviation of limited number of experiments gives too wide range for practical acceptance. A possible solution of handling calculated results using simplified prediction method is the following:

- if the calculated result is less than the requirement (in the figure R'_w= 52 dB) the construction chosen is not correct from the point of view of sound insulation quality;
- if the calculated result is between R'_w= 52 dB and 54 dB the situation is uncertain, detailed calculation or the study of analogue situations are necessary;
- if the calculated results are over R'_w=54 dB the constructional solution is acceptable.

5. CONCLUSION

The paper describes some additional elements, considerations and procedures which extend the possible applicability of the simplified prediction method, published in [1]. Also consideration of the accuracy and handling the calculated data are presented. These contributions are inside the frames of the predicting method in [1] but give more possibilities of using it.

ACKNOWLEDGEMENT

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